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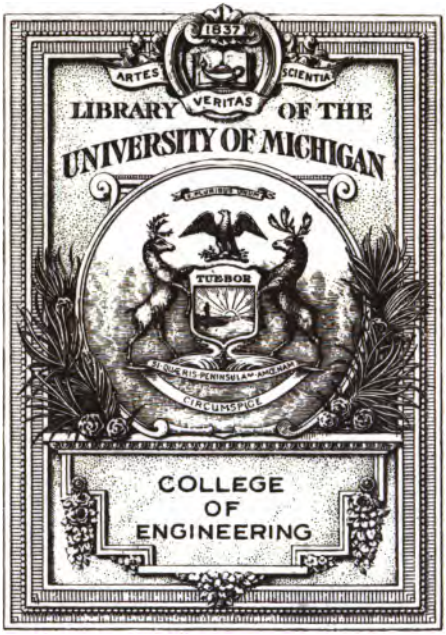

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Volume II. *In Press.* Others of the Series of Industrial Texts in preparation.

CONCRETE WORK

A BOOK TO AID THE SELF-DEVELOPMENT OF WORKERS IN CONCRETE AND FOR STUDENTS IN ENGINEERING

BY

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VOLUME I

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WALTER C. VOSS

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MR. LEONARD WASON, PRESIDENT OF THE ABERTHAW
CONSTRUCTION COMPANY, WHO THROUGH CONSTRUCTION AND EDUCATIONAL EFFORT
HAS SO GREATLY ADVANCED
THE ART OF CONCRETE
CONSTRUCTION.

338330

NOTE BY EDITOR OF THE INDUSTRIAL TEXTS

One of the outstanding achievements of the War was the successful training of 130,000 soldiers in the various vocations and trades connected with military operations. This training was conducted in 147 schools scattered throughout the country, and was under the supervision of a corps of technical experts connected with the Committee on Education and Special Training of the War Department. The Industrial Texts of the Technical Series were planned to conserve the results of this vast educational undertaking and to make available the methods and materials thus acquired for the still greater task of training men for the nation's industries.

The present volume on Concrete Work is the first of these texts. One of the authors, Professor W. K. Hatt, planned and supervised the army training in Concrete Construction. The other, Mr. Walter C. Voss, had immediate charge throughout the war of the training given in this subject to the detachments detailed at Wentworth Institute, Boston, Mass. Thus these two authors have put into this work not only the results of years of experience in the practical teaching of Concrete Construction to technical students, but also the unusual experience of conducting highly intensive courses under the stress of war conditions.

W. H. Timbie.

PREFACE TO VOLUME I

Concrete Construction, which is annually filling a larger place in the building industry, needs a larger supply of trained operatives and foremen, who can work, as often they must do, away from the close supervision of technical directors.

The purpose of these volumes is to extend the scope of work now possible to the concrete worker of unguided experience by bringing him to an intelligent understanding of the scientific principles underlying his art, and by introducing him to the wider opportunities that exist for him in modern concrete construction. By these means it is hoped that more concrete workers will develop to the competency of foremen or local contractors for concrete construction.

Some definite steps have been taken toward a supply of properly trained mechanics for this industry. Those organizations which operate systems of training for their new men will probably maintain a supply of experienced workmen, who accomplish the end the employer has in view; but in many cases the men will be unable, from practical application only, to rise to the level which their mental and physical traits make possible. The question of output is foremost, and the mental development of the worker a secondary consideration. Only in rare instances does this type of training develop a well-rounded man. It does not provide for the man whose ambition to undertake wider responsibilities is the motive force for further study and guided experience.

The evening schools and correspondence courses throughout the country bear witness to the fact that the so-called practically trained man realizes his handicap, as his connection with a trade progresses.

The authors have attempted to span the gulf between the trained mechanic and the foreman. It is hoped that these volumes will consolidate and explain the experiences of the trained mechanic. For the novice the authors have supplied a combination of study of principles and guided performance of jobs, so that he may gradually acquire a well-rounded training.

Experience is a good teacher, but guided experience is far better. The worker on the large construction company's force continually sees things which he cannot explain. He wonders how various conclusions are arrived at. He hears decisions made, which he cannot analyze. These may eventually so stir up his ambition that he determines to go to the root of the problem. He may enroll in an evening school and spend his free hours in the study of abstract matters, apart from the realities of his daily work.

However, students should be so trained that their interest is aroused by the practicality and definite usefulness of their studies. These should be attached to a real situation, and their use should be apparent at the time they are studied. For instance, the workman sees a cast-iron frame built into a concrete structure. He is told to "build in these scuppers, so and so." This trade-name sticks with him. He handles the piece, sees how it operates, and thus comes the desire to know why it is used. Then is the time to study about scuppers, cast iron, fire hazards, and the like. He then not only gains experience, but ties this experience into usable structural information.

It is by means of the job, attached to a construction that gives it meaning, that the authors train the novice. Their hope is that this book, based on this principle, will appeal to the workman in the field. Step by step the student studies the entire construction of a single building, taking up such technical data as are necessary, when the actual value of such study becomes apparent to the student.

In preparing these volumes the authors have obtained material from many sources. They wish to express their indebtedness to the manufacturers of building material and equipment, in particular, for photographs and information without which the books would be incomplete. They wish to acknowledge their appreciation of the review of the Chapter on Estimating by Mr. Clayton W. Mayers of the Aberthaw Construction Company; the coöperation of the Aberthaw Construction Company in supplying the figures credited to them in the text; the help of the Portland Cement Association; to the authors of the various texts on Concrete Construction mentioned throughout the book; to those in charge of the Training Detachments of the U. S. Army; and to the students who by their interest and workmanship have enabled the authors to include most of the figures in the books.

It is hoped that this humble start will lead to more constructive pedagogy in the study of concrete construction.

The subject is presented in two volumes. Volume I contains the development of principles and information of methods of construction and standards, necessary for the construction of the definite building. Volume II contains a number of jobs, by accomplishing which, the worker will learn the how and why of the elements entering into concrete constructions. The two volumes should be used together. The ideas back of Volume II and the suggestions for its use are further developed in the preface to that volume.

W. K. H.
W. C. V.

LAFAYETTE, IND.
BOSTON, MASS.
July, 1920

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CONCRETE WORK

CHAPTER I

OPPORTUNITIES IN THE CONCRETE INDUSTRY

1. The Need for Study. Thirty years ago the use of concrete was limited, and its use in building construction was accompanied by risks such as few were willing to assume. It was therefore being used mostly for constructions which did not endanger life, and which did not involve any great amount of chance.

At that time, Randolph, Sr., was Austin's most prominent builder and jobber. The more progressive selectmen of Austin wanted the old wooden and stone walks **replaced with concrete.** Randolph had as much chance as anyone else to branch out into this sort of work. Who knew much about it then? He made the change, and after training himself with the new material at the expense of costly mistakes, he gradually overcame the many obstacles which such an entire change of conditions naturally brought about.

His town was growing rapidly. Concrete construction, however, was progressing still more swiftly. The Lawlor Company of New York was planning to erect a small shop in Austin, and they were insistent upon fireproof construction and wanted a **concrete** building. The possibility of a more progressive contractor coming into town from without was imminent. But Randolph & Son had always had a healthy business in walks, and why should they care? Young Randolph could not view the situation with as much unconcern as his father. They must make a proposal for this new building. But it had up-to-date footings, retaining walls, a concrete frame, and all the equipment that a progressive firm would need. This involved forms, steel placing, and the mixing of concrete that would span distances unsupported, and which would in some cases bear column loads. How was this to be done? Surely a wide gulf had developed between their experiences, which had brought them a satisfactory annual stipend, and the experiences which were needed to make them **real contractors** and which would make the formation of a contracting corporation of sizeable proportions possible.

This possibility grew in importance in the mind of Randolph, Jr., until he decided to **train** himself in this work and incidentally examine the possibilities of such a venture. The most rapid, accurate, and result-producing course was quite a problem. He finally decided to take his best workman and **hire out upon a job** of this type, but larger, until the project of the Lawlor Company materialized.

Prob. 1*a*. What risks were contractors assuming in the early construction of concrete buildings?

Prob. 1*b*. What advantages have concrete walks over the old stone and wooden walks?

2. The Progress of Concrete Construction. The most noticeable feature of their experience, at first, was the efficiency which this industry had developed. Everything was done systematically. No time was wasted in useless motions on the part of the workmen. Indeed it was a lesson to them, even for their walk construction. The materials, as they came upon the job, were **tested** and **analyzed.** The mix was not always the same. Large systems of equipment were worked out in detail. Progress reports were made daily. There was even a volume of information connected with concrete protection. Slowly, their attention was shifted from the general view to **details** of construction.

Definite interest in their future led them to become proficient in many of the processes and in the technique of carrying on the work. They were **not merely** laborers; they were **students** on the job, acquiring information by a liberal use of all their senses. They learned about footings, foundation walls, columns, beams, slabs, piers, retaining walls, curbs, gutters, and the relation that the other materials, such as wood, brick, tile, artificial stone, and steel, bore to the construction.

All these operations were carried on in strict conformity with well-prepared **plans, details,** and **specifications.** Much was the information they acquired of plan-reading, seemingly so unnecessary in building walks. This surely would be invaluable in estimating any of their future work, and in making any necessary details which would be required by their workmen in the interpretation of the general plans.

The Lawlor project came along, Randolph & Son received the job, and thus the experience was to be put to a test. The wide gulf was being slowly bridged and an avenue of possibility was opened which would lead to success in direct proportion to the continued **study of present practice** and to the developments and improvements they might be responsible for.

Step by step, as they combined study and experience, Randolph & Son became reputable "concrete" men. They applied their experience on the Lawlor shop. **They made mistakes.** They had interpreted some of their experiences wrongly. They found constructions in this new building, which, though simple, required special treatment. This they had not anticipated. Their training had been **without definite guidance** from experienced and interested sources. The student also learns by mistakes which are as much a part of his training as his successes. These are not parts of a product which must satisfy an owner and an architect.

The experience of Randolph & Son is just the repetition of the story of many small contractors who have been progressive. There are some who have grown from small-town cement-walk men to the large corporations which today operate on an extensive scale. Parallel with their experiences are those of the tradesmen who are ambitious to become foremen or superintendents. The training and experience underlying both advancements are the same.

As time goes on the improvements which such well trained artisans introduce will bring the cost of the concrete building down to a point where it will be the exception to build of other structural materials. Concrete buildings are now being made the object of study by progressive architects the country over and manufacturers are straining every nerve to turn out products which will make this type of building an architectural structure, as well as an economic and permanent one.

A review of the Portland cement production since 1880 will enable one to judge the gigantic strides this industry is taking.

TABLE I *

BARRELS OF PORTLAND CEMENT PRODUCED SINCE 1880

Year	Production	Year	Production
1880	42,000	1909	64,991,431
1885	150,000	1910	76,549,951
1890	335,500	1911	78,528,637
1891	454,813	1912	82,438,096
1895	990,324	1913	92,097,131
1898	3,692,284	1914	88,230,170 (war)
1900	8,482,020	1915	85,914,907
1902	17,230,644	1916	91,521,198
1903	22,342,973	1917	92,814,202
1905	35,246,812	1918	71,081,663
1908	51,072,612	1919 (est.)	80,287,000

In the main, the present concrete work that is being done is of the **reinforced type.** The work requires the services of the expert, both in its design and in its erection. Because of its use by the amateur contractor, who had little or no knowledge of its limitations and much less of the proper methods of its placement, the industry passed through a period of trying disrepute. That time has passed. The most competent engineers are now interested in proper design and few contracts are being let to the builder who cannot produce credentials of his ability to handle the work. These contractors in turn are selecting their workmen and foremen with the utmost care. The foreman, who, by virtue of his diligence in the **study** of the proper erection and economical handling of the materials and plant, can show signs of **increased output,** is the man who is climbing with his organization.

---

* Mineral Resources, U. S. Geol. Survey.

"Reinforced concrete is found in the deepest foundations, and even in the piles upon which the masonry rests. It forms the roof of the structure, and the spires and highest chimneys are made of this material. It is in use in the floors, the ceilings, the walls, the stairs, the cornices, and the handrailings of buildings of every kind. The **railroad engineer** uses reinforced concrete for ties, for culverts, for arches, for tunnel portals, for round houses, bumping posts, and for train sheds. The **hydraulic engineer** builds his dam in the wilderness and his fountains in the city of a combination of cement and iron. The **surveyor** uses reinforced concrete boundary fence posts, and the **electrical engineer** uses poles for transmission lines similarly strengthened. The **municipal engineer** in his designs for sidewalks, curbing, culverts, and sewer pipe, and the **naval architect** in his rather experimental designs of barges, testify to the great variety of uses to which this type of construction may be adapted." *

Such a field is the area for action in which the "concrete" man can operate. Varieties that enable work to be carried on in any season of the year, change of occupation that does away with monotony, and an **unbounded opportunity** for study along very broad lines, surely offer an attractive vocation to one who delights in doing.

* Brooks' "Reinforced Concrete," p. 4; McGraw-Hill Publishing Company.

Prob. 2*a*. Examine the daily progress report of a superintendent to his main office, for some building being erected in your vicinity. What information is given? How is this information of use to the Chief Engineer? To the Employment Manager? To the Estimating Department?

Prob. 2*b*. In the year 1885 the production of Portland cement was 150,000 barrels. In the year 1890 the amount of cement produced had risen to 335,500 barrels. What was the increase and per cent of increase of 1890 over 1885?

Solution.	Amount produced in 1890.......	335,500 bbls.
	Amount produced in 1885.......	150,000 bbls.
	Increase over 1885..............	185,500 bbls.

Using 1885 as 100 per cent, the increase of 1890 over 1885 would be

$$185{,}500 \div 150{,}000 \times 100\% = 123.67\% \ (124).$$

In determining percentages the base value, such as 150,000 in this case, is considered a whole or 100 per cent. The percentage then is

$$\text{Increase} \div \text{Base} \times 100\%.$$

Prob. 2*c*. What was the percentage of increase in the production of cement in 1900 over 1890?

Prob. 2*d*. What percentage of all the cement produced from 1910 to 1917, inclusive, was manufactured in 1917?

Prob. 2*e*. What per cent of reduction over 1913 was caused by the war?

Prob. 2*f*. Assuming that the towers of the Hell Gate bridge were placed during 1916, and that approximately 594,000 bags of cement, at 4 bags to the barrel, were used, what percentage of the entire output for the year was used on this project?

Prob. 2*g*. What percentage of the yearly output would a contractor, who used 750,000 barrels of cement in 1917, be consuming?

3. Problems for Review.

Prob. 3*a*. If the yearly demand for cement in 1917 was the same as that in 1916, what percentage of reduction in cost could we reasonably expect?

Prob. 3*b*. If the demand for cement in 1910 was 40 per cent greater than in 1909, what reasonable effect should this have on the price of cement, considering the amount produced in each year?

Prob. 3*c*. If a bag of cement is considered one cubic foot, how many cubic feet of aggregate were necessary to use up the cement produced in 1910 if it were mixed as follows:

40 per cent	1 to 9
50 per cent	1 to 6
10 per cent	1 to 4½

Prob. 3*d*. Assuming that one bag of cement and 6 cubic feet of aggregate will make 6 cubic feet of concrete, how many yards of concrete, of this mix, could be poured with the cement produced in 1918?

Prob. 3*e*. If 200 barrels of cement are considered a minimum car-load, and a job requires only 175 barrels, would it be wiser to buy direct from the mill at $2.73 per barrel, with a charge of 15 cents per barrel for cartage, or to buy from a local dealer, delivered, at $3.25 per barrel, if the excess barrels of cement could be sold at $3.00 each? What profit or loss would result? What would be the cost per barrel if bought from the mill under these conditions?

Prob. 3*f*. The proportion of cement to aggregate in a concrete mixture is 1 to 6 and cement can be purchased at $2.75 per barrel, net, while the aggregate costs $2.25 per yard. What effect on the cost would a 10 per cent increase in the cost of cement and a 20 per cent decrease in the cost of the aggregate have? What percentage of increase or decrease in cost is entailed?

CHAPTER II

PLANS, DETAILS, AND SPECIFICATIONS

4. Plans and Specifications for Estimates. One of the most elementary abilities which the successful foreman or contractor must possess, is that of **reading and interpreting plans and specifications.** They usually come to him as general drawings, with just enough details to enable him to make a reasonably correct estimate. The specifications are for the purpose of clearing up any questions which might arise in his mind relating to fixtures, types of finish, mixes of concrete, and so forth. They also provide for the work of the sub-contractors, and describe their work and the relations existing between them and the general contractor.

With this in mind the student is furnished with a set of plans and specifications of a small vise shop for the Lawlor Company. By a **guided** study of the various parts of this building and their erection, he should pass through the experiences which the contractor has in the construction of this building or one of a similar type.

The plans which the contractor would receive in the form of blueprints, for this building, are shown on Plates I to VII, followed by the Specifications on pages 17 to 24.

The plans include:

		Plate
Sheet 1.	Footing Plan	I
Sheet 2.	Ground Floor Plan	II
Sheet 3.	Roof Plan	III
Sheet 4.	Elevations	IV
Sheet 5.	Sections	V
Sheet 6.	Concrete Details	VI
Sheet 7.	Door and Window Details	VII

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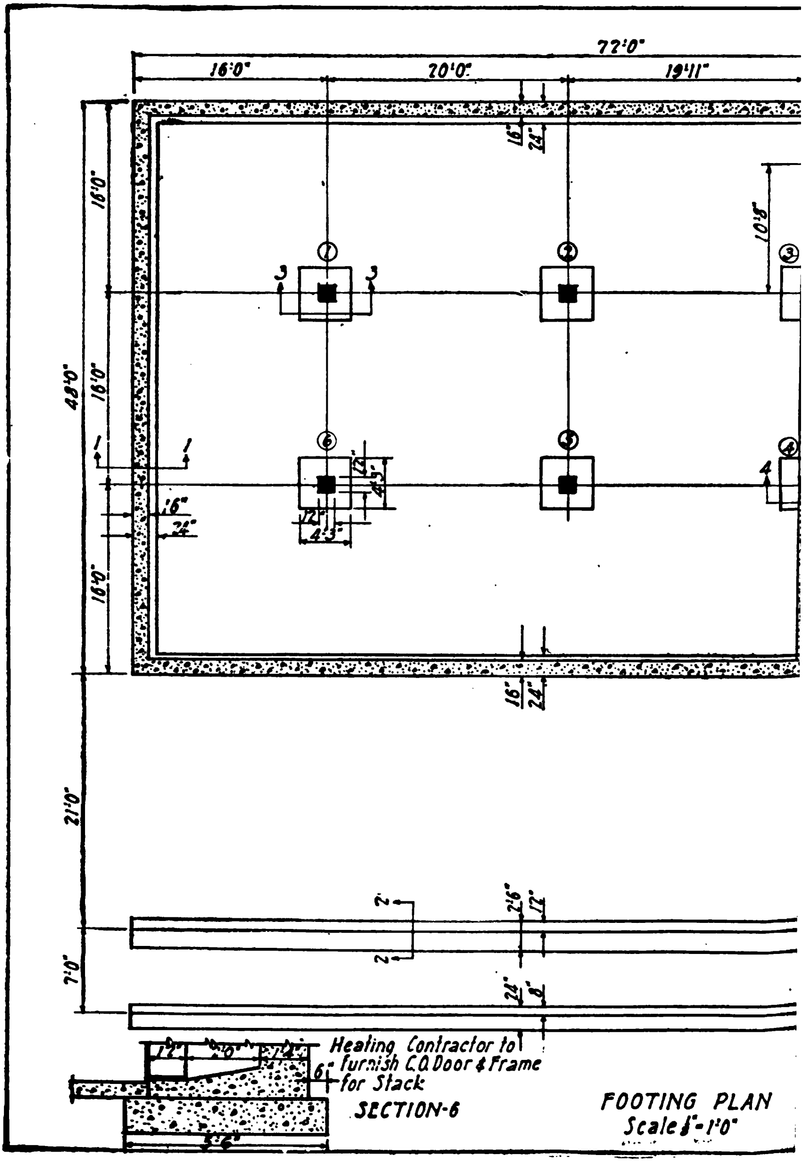
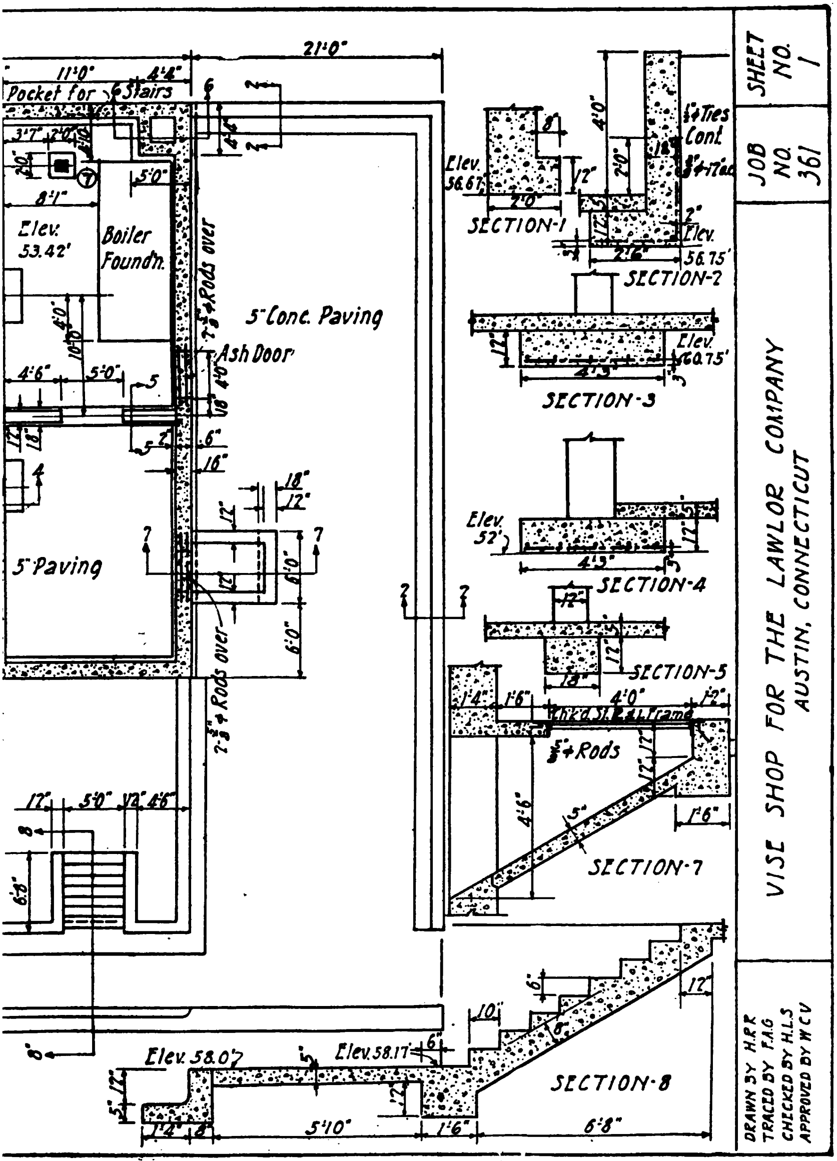


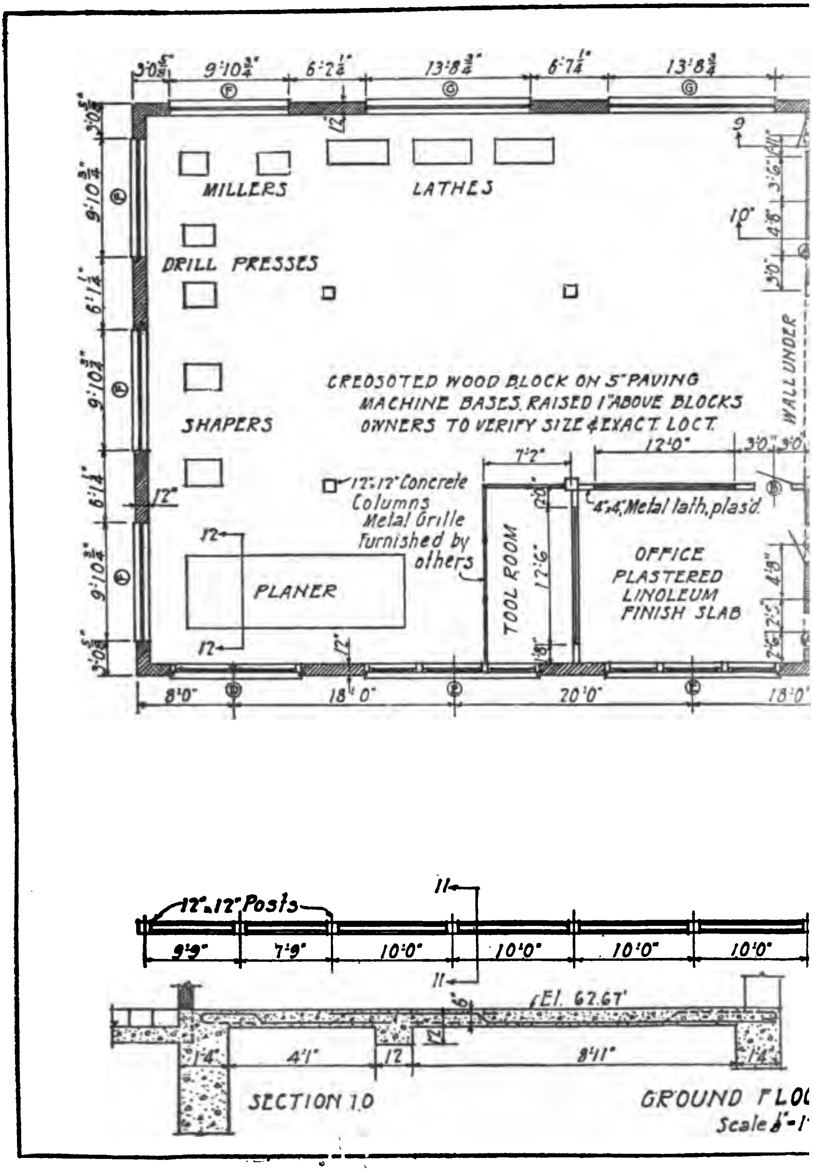
FOOTING PLAN
Scale 1/8"=1'0"

Pl

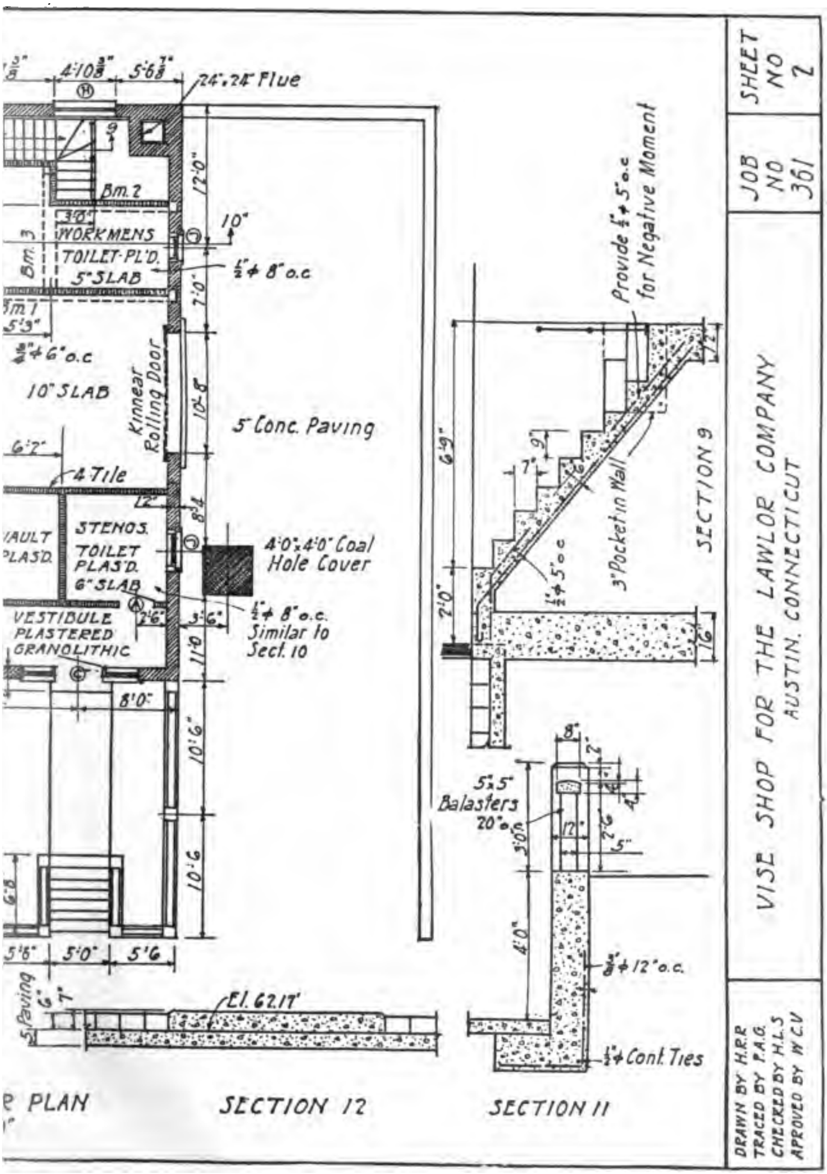

SHEET NO. 1
JOB NO. 361
VISE SHOP FOR THE LAWLOR COMPANY
AUSTIN, CONNECTICUT
DRAWN BY H.R.R
TRACED BY F.A.G
CHECKED BY H.L.S
APPROVED BY W.C.V
21'0"
11'0"
4'4"
Pocket for Stairs
Elev. 53.42'
Boiler Found'n.
5" Conc. Paving
Ash Door
7-5/8"φ Rods over
5" Paving
SECTION-1
Elev. 56.67'
SECTION-2
1/4"φ Ties Cont.
Elev. 56.75'
SECTION-3
Elev. 60.75'
SECTION-4
Elev. 52'
SECTION-5
SECTION-7
Ch'k'd St. Pl. L Frame
5/8"φ Rods
SECTION-8
Elev. 58.07
Elev. 58.17
5'10"
6'8"

ATE I.

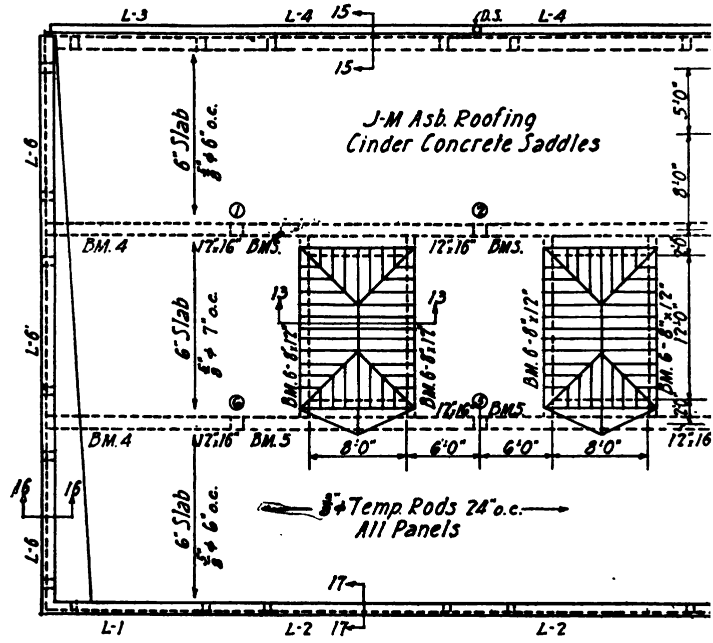
MU


MILLERS
LATHES
DRILL PRESSES
SHAPERS
CREOSOTED WOOD BLOCK ON 5" PAVING
MACHINE BASES RAISED 1" ABOVE BLOCKS
OWNERS TO VERIFY SIZE & EXACT LOC'T.
12"x12" Concrete Columns
Metal Grille furnished by others
PLANER
TOOL ROOM
4"x4" Metal lath, plas'd.
OFFICE PLASTERED LINOLEUM FINISH SLAB
WALL UNDER
12"x12" Posts
El. 62.67'
SECTION 10
GROUND FLO
Scale 1/8"=1'
3'0 5/8"
9'10 3/4"
6'2 1/4"
13'8 3/4"
6'7 1/4"
13'8 3/4"
8'0"
18'0"
20'0"
18'0"
7'2"
12'0"
12'6"
9'9"
7'9"
10'0"
4'1"
8'11"

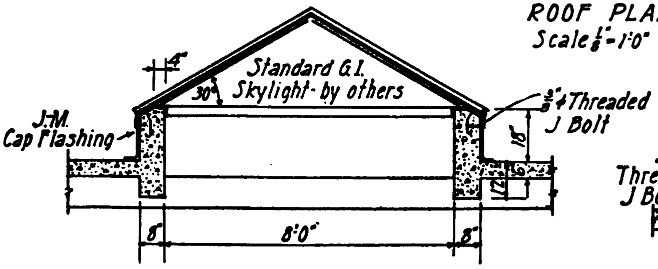
PLA


4'10 3/8"
5'6 7/8"
24"×24" Flue
Bm.2
3'0"
Bm.3
WORKMENS TOILET-PL'D.
5" SLAB
10"
1/2"ϕ 8" o.c
12'0"
7'0"
Bm.7
5'3"
3/8"ϕ 6" o.c
10" SLAB
Kinnear Rolling Door
10'8"
5" Conc. Paving
6'2"
4 Tile
12"
8'4
VAULT PLAS'D.
STENOS. TOILET PLAS'D. 6" SLAB
4'0"×4'0" Coal Hole Cover
1/2"ϕ 8" o.c. Similar to Sect. 10
VESTIBULE PLASTERED GRANOLITHIC
2'6"
3'6"
11'0"
8'0"
10'6"
10'6
6'8
5'6"
5'0"
5'6
5" Paving
6"
7"
El. 62.17'
PLAN
SECTION 12
SECTION 11
Provide 1/2"ϕ 5" o.c for Negative Moment
6'9"
9"
7"
2'0"
1/2"ϕ 5" o.c
3" Pocket in Wall
SECTION 9
12"
16"
8"
2"
5"×5" Balasters 20" o.c.
3'0"
12"
2'6"
5"
4"
4'0"
3/8"ϕ 12" o.c.
1/2"ϕ Cont. Ties
SHEET NO 2
JOB NO 361
VISE SHOP FOR THE LAWLOR COMPANY
AUSTIN, CONNECTICUT
DRAWN BY H.R.R
TRACED BY P.A.G.
CHECKED BY H.L.S
APPROVED BY W.C.V

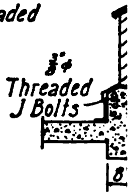
TE II.

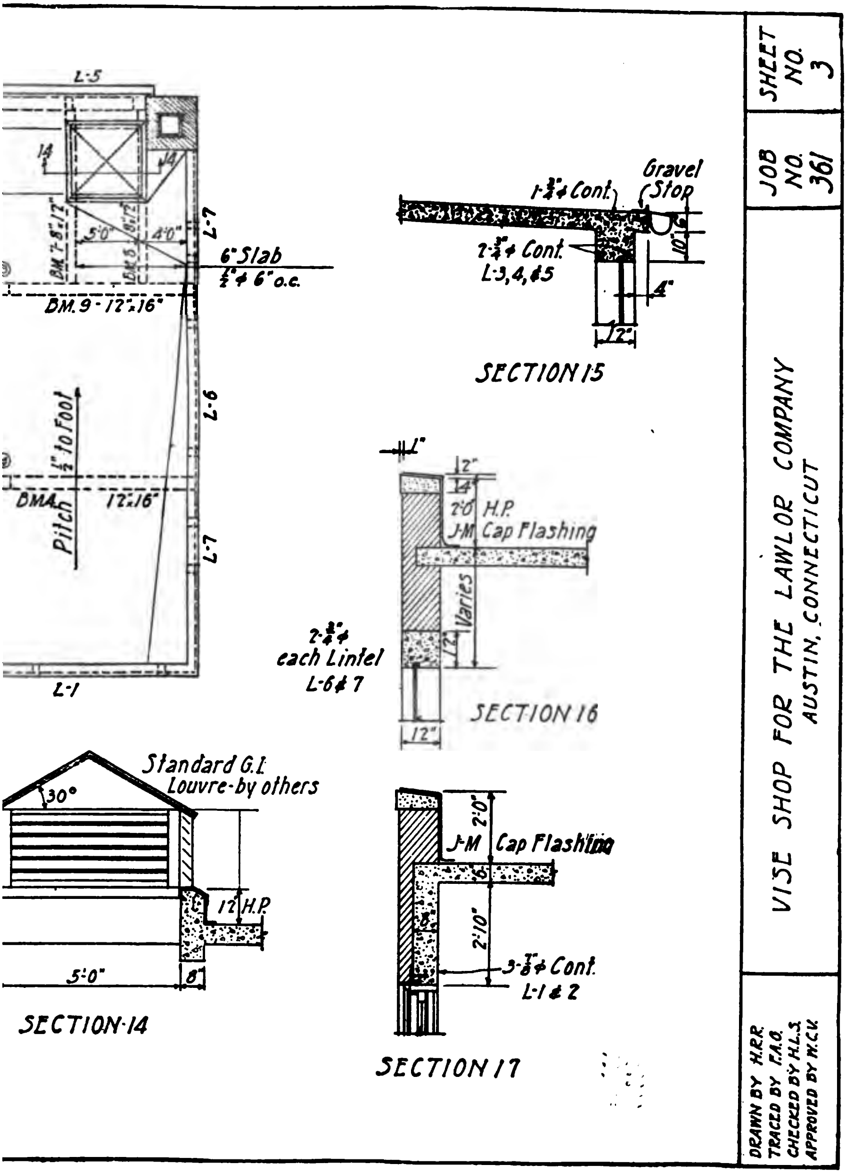


ROOF PLAN
Scale 1/8"=1'0"



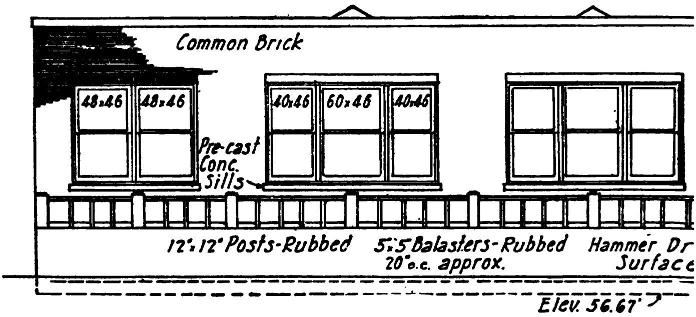
SECTION-13



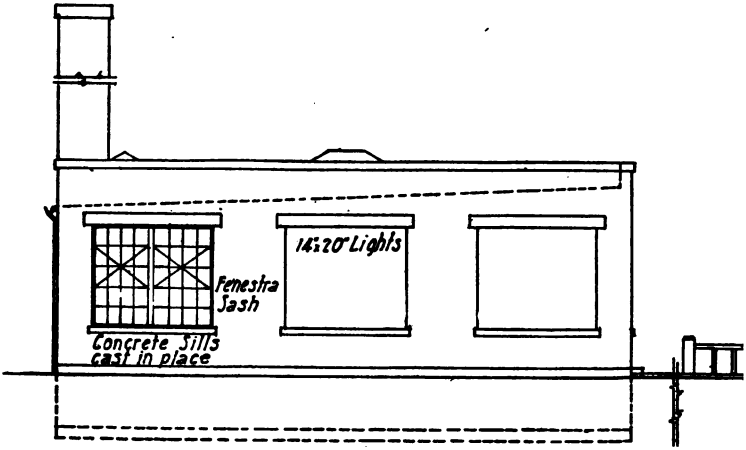

L-5
14
14
BM. 7-8"x12"
BM. 8-8"x12"
5'0"
4'0"
L-7
6" Slab
½" ⌀ 6" o.c.
BM. 9 - 12"x16"
Pitch ½" to Foot
L-6
BMA 12"x16"
L-7
L-1
Gravel Stop
1-¾" ⌀ Cont.
2-¾" ⌀ Cont.
L-3, 4, & 5
10½"
4"
12"
SECTION 15
1"
2"
14"
2'0" H.P.
J-M Cap Flashing
Varies
12"
2-¾" ⌀
each Lintel
L-6 & 7
12"
SECTION 16
Standard G.I.
Louvre-by others
30°
12" H.P.
5'-0"
8"
SECTION-14
2'0"
J-M Cap Flashing
6"
2'10"
3-⅞" ⌀ Cont.
L-1 & 2
SECTION 17
SHEET NO. 3
JOB NO. 361
VISE SHOP FOR THE LAWLOR COMPANY
AUSTIN, CONNECTICUT
DRAWN BY H.R.R.
TRACED BY F.A.O.
CHECKED BY H.L.S.
APPROVED BY W.C.V.

TE III.

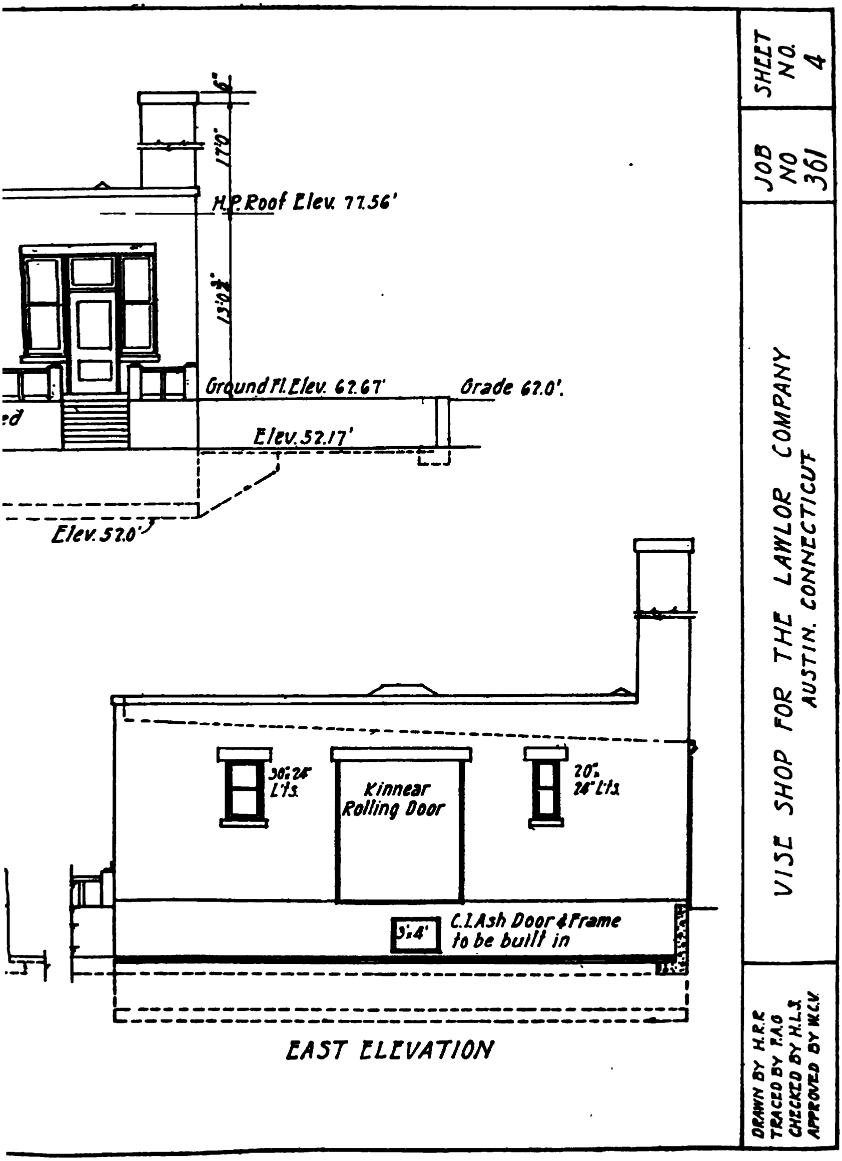
UM



SOUTH ELEVATION

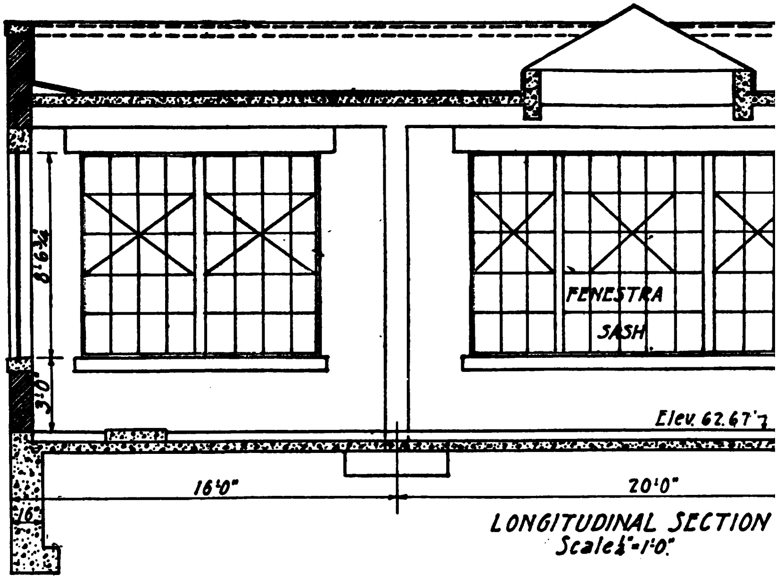


WEST ELEVATION

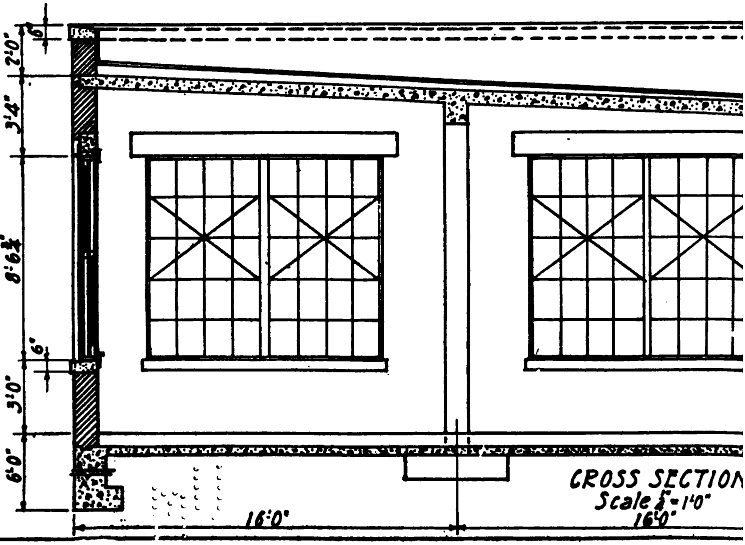

6"
17'0"
H.P. Roof Elev. 77.56'
13'0"
Ground Fl. Elev. 62.67'
Grade 62.0'.
ed
Elev. 52.17'
Elev. 52.0'
30"x 24" L'ts.
Kinnear Rolling Door
20"x 24" L'ts.
C.I. Ash Door & Frame to be built in
3'x 4'
EAST ELEVATION
SHEET NO. 4
JOB NO 361
VISE SHOP FOR THE LAWLOR COMPANY
AUSTIN. CONNECTICUT
DRAWN BY H.R.R.
TRACED BY T.A.G.
CHECKED BY H.L.S.
APPROVED BY W.C.V.

ATE IV

MU

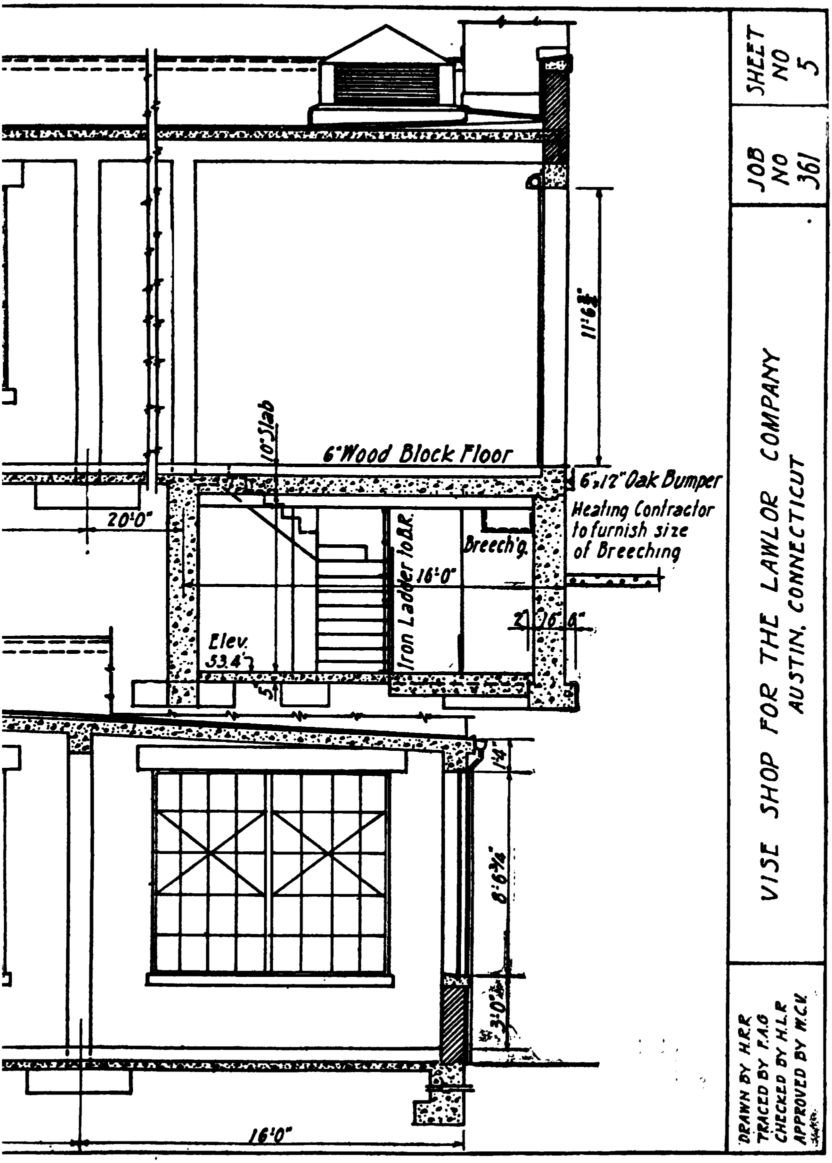


LONGITUDINAL SECTION
Scale ¼"=1'0"



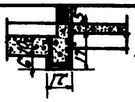
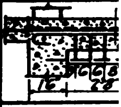
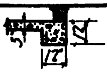
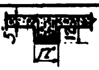
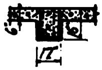
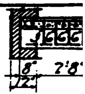
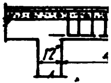
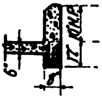
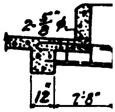
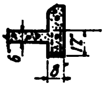
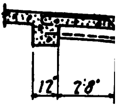
CROSS SECTION
Scale ¼"=1'0"

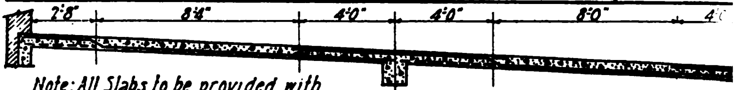
P


6"Wood Block Floor
10"Slab
11'6¾"
6"x12" Oak Bumper
Heating Contractor to furnish size of Breeching
Breech'g.
Iron Ladder to B.R.
16'0"
20'0"
2' 16' 6"
Elev. 53.4'
5'
14"
8'6¾"
3'0"
16'0"
SHEET NO 5
JOB NO 361
VISE SHOP FOR THE LAWLOR COMPANY
AUSTIN, CONNECTICUT
DRAWN BY H.R.R.
TRACED BY F.A.G.
CHECKED BY H.L.R.
APPROVED BY W.C.V.

ATE V.

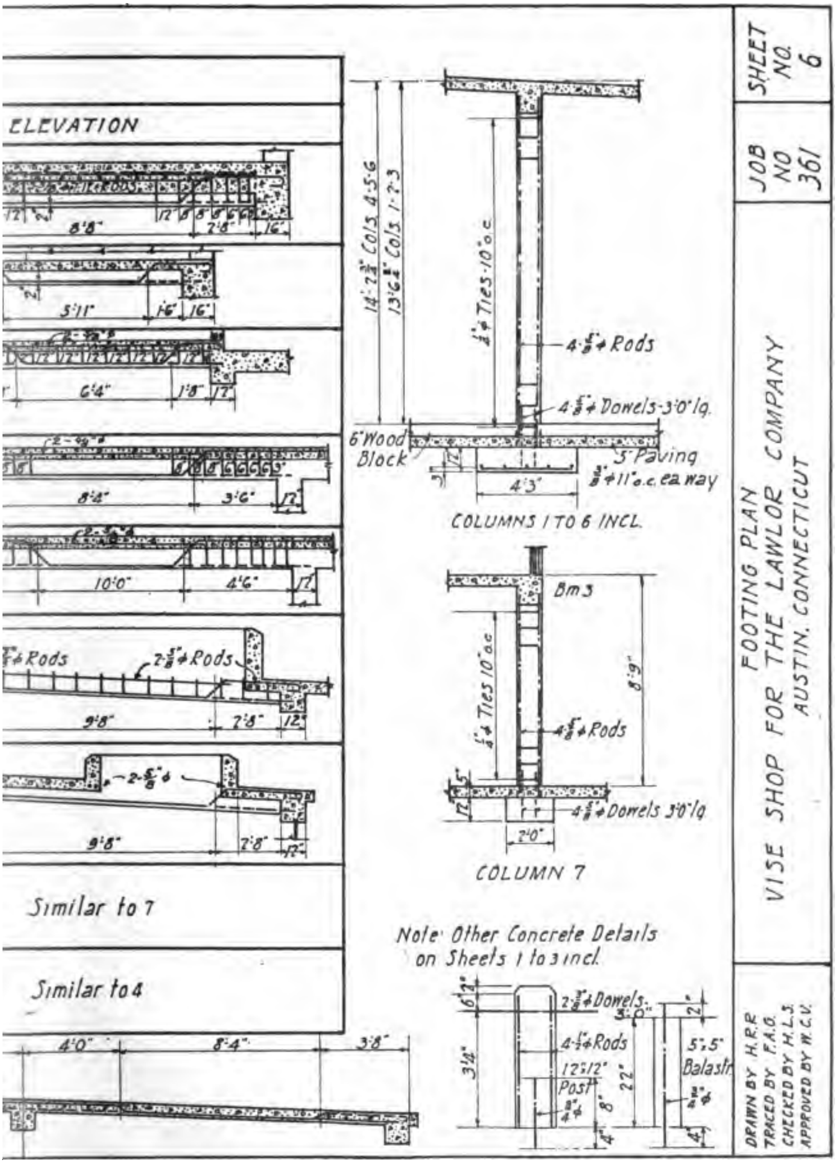
BEAM SCHEDULE

BEAM		LOCATION	TENSION			SHEAR			SECTION	
NO.	QUANT.		NO.	SIZE	SHAPE	NO.	SIZE	SHAPE		
1	1	Ground Floor	2 2	$1\frac{1}{8}''\phi$ $1\frac{1}{8}''\phi$	Str ⌴	14	$\frac{3}{8}''\phi$	⊔		
2	1	Ground Floor	2 2	$\frac{1}{2}''\phi$ $\frac{1}{2}''\phi$	Str ⌴		None			
3	1	Ground Floor	2 2	$\frac{3}{4}''\phi$ $\frac{3}{4}''\phi$	Str. ⌴	10	$\frac{3}{8}''\phi$	⊔		COL 7
4	3	Roof	2 2	$1''\phi$ $1''\phi$	Str ⌴	16	$\frac{3}{8}''\phi$	⊔		
5	4	Roof	2 2	$1''\phi$ $1''\phi$	Str. ⌴	16	$\frac{3}{8}''\phi$	⊔	Similar to 4	
6	4	Skylight	2 1	$\frac{7}{8}''\phi$ $\frac{7}{8}''\phi$	⌴ Str.	15	$\frac{3}{8}''\phi$	Ʊ		
7	1	Louvre	2 1	$\frac{5}{8}''\phi$ $\frac{5}{8}''\phi$	⌴ Str.		None			
8	1	Louvre	2 1	$\frac{3}{4}''\phi$ $\frac{3}{4}''\phi$	⌴ Str.	3 3	$\frac{3}{8}''\phi$ $\frac{3}{8}''\phi$	⊔ Ʊ	Similar to 7	
9	1	Roof	2 2	$1''\phi$ $1''\phi$	⌴ Str.	12	$\frac{3}{8}''\phi$	⊔	Similar to 4	

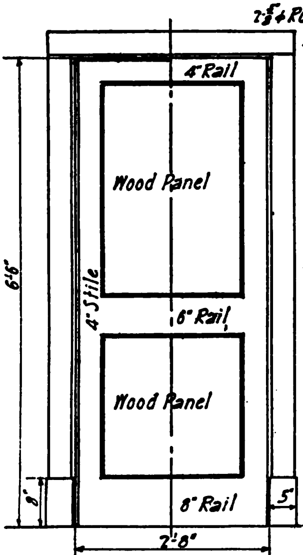


Note: All Slabs to be provided with alternate bent Rods as shown

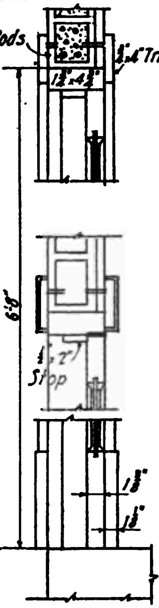
SLAB DETAIL


ELEVATION
8'8"
7'8"
16"
5'11"
1'6"
16"
6'4"
1'8"
17"
8'4"
3'6"
12"
10'0"
4'6"
17"
2-5/8"φ Rods
9'8"
7'8"
12"
2-5/8"φ
9'8"
7'8"
17"
Similar to 7
Similar to 4
4'0"
8'4"
3'8"
14'-7 3/4" Cols 4-5-6
13'6 1/4" Cols 1-2-3
1/4"φ Ties 10" o.c.
4-5/8"φ Rods
4-5/8"φ Dowels 3'0" lg.
6" Wood Block
5" Paving
3/8"φ 11" o.c. ea way
4'3"
COLUMNS 1 TO 6 INCL.
Bm 3
1/4"φ Ties 10" o.c.
8'9"
4-5/8"φ Rods
4-5/8"φ Dowels 3'0" lg
2'0"
COLUMN 7
Note: Other Concrete Details on Sheets 1 to 3 incl.
2-3/8"φ Dowels 3'0"
4-1/4"φ Rods
12"×12" Post
3'4"
22"
8"
3/4"φ
5"×5" Balastr
2"
4"
3/4"φ
SHEET NO. 6
JOB NO 361
FOOTING PLAN
VISE SHOP FOR THE LAWLOR COMPANY
AUSTIN, CONNECTICUT
DRAWN BY H.R.R.
TRACED BY F.A.G.
CHECKED BY H.L.S.
APPROVED BY W.C.V.

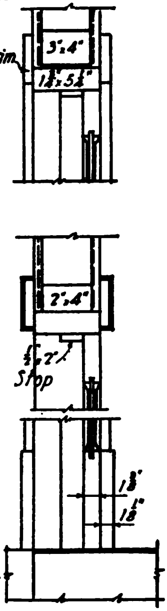
TE VI.



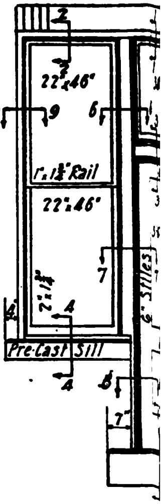
ELEVATION Ⓐ & Ⓑ
Scale ¾"=1'-0".



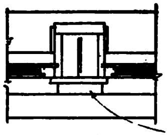
SECTION Ⓐ



SECTION Ⓑ
Scale 1½"=1'-0"

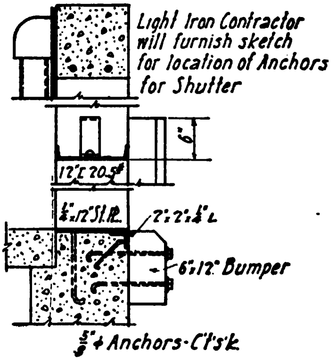


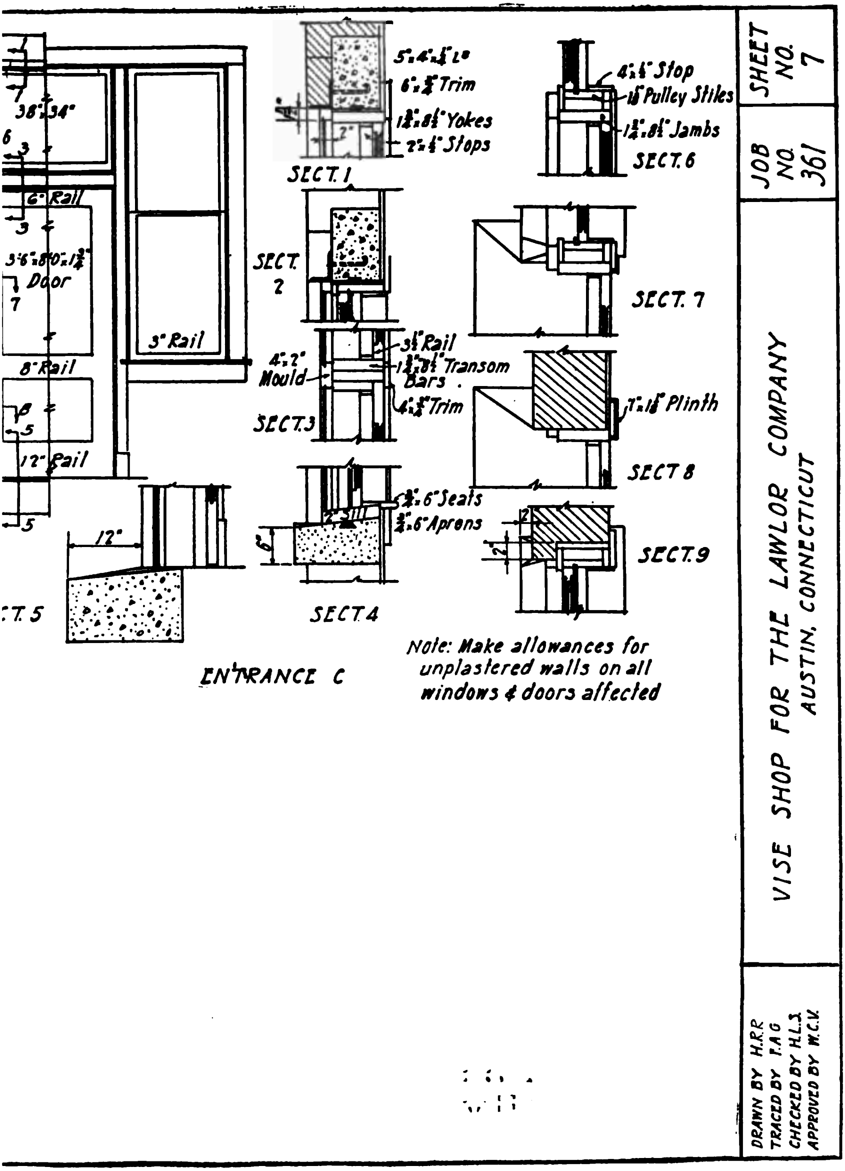
SEC



MULLION SECTION
WINDOWS D&E

HEAD SECTION SAME AS ② Ⓒ
JAMB " " " ⑨ Ⓒ
SILL " " " ④ Ⓒ
WINDOWS J SIMILAR FOR GLASS
FOR GLASS-SIZES SEE SH. NO. ④
WINDOWS Ⓕ TYPE STEEL SASH DET.


Light Iron Contractor will furnish sketch for location of Anchors for Shutter
6"
12"I 20.5#
½"x12" Sl. Pl.
2"x2"x¼" L
6"x12" Bumper
⅝"⌀ Anchors-Ct'sk.


38"×34"
6'' Rail
3'6"×8'0"×1¾"
Door
3" Rail
8" Rail
12" Rail
12"
T. 5
5"×4"×½" L°
6"×⅞" Trim
1¾"×8½" Yokes
2"×½" Stops
SECT. 1
SECT. 2
4"×2" Mould
3½" Rail
1¾"×8½" Transom Bars
4"×⅞" Trim
SECT. 3
1⅝"×6" Seats
⅞"×6" Aprons
6"
SECT. 4
ENTRANCE C
4"×½" Stop
1⅛" Pulley Stiles
1¾"×8½" Jambs
SECT. 6
SECT. 7
7"×1⅛" Plinth
SECT. 8
2
2
SECT. 9
Note: Make allowances for unplastered walls on all windows & doors affected
SHEET NO. 7
JOB NO. 361
VISE SHOP FOR THE LAWLOR COMPANY
AUSTIN, CONNECTICUT
DRAWN BY H.R.R.
TRACED BY T.A.G.
CHECKED BY H.L.S.
APPROVED BY W.C.V.

TE VII.

p

o

p

i

n

U

h

t

To **read such plans** requires the ability of **making** them; perhaps not the technique of the draftsman, but the sense of interrelation which enables one to picture the parts, piece by piece, as they can, and should go together. **Drawings are the language by which the designer speaks to the workman.** They should do away with lengthy explanations. Unless the workman is able to visualize his work from them, he is at loss, much as if he were listening to verbal instructions in a language foreign to him.

Prob. 4*a*. Why are the dimensions for the footings for columns 1, 2, 3, 4, and 5 not shown on Plate I?

Prob. 4*b*. What is the area of the building as shown on Plate I, from building line to building line, in both directions? What percentage of this area is composed of concrete walls? What percentage of concrete columns? What percentage of footings is there in plan?

Prob. 4*c*. In the details for Entrance *C*, Plate VII, the elevation is shown differently on each side of the vertical dash center line. Why?

(*As a preparation for the reading of plans and the drawing of simple projections the Jobs Nos. 1 to 9, Vol. II, should be performed.*)

5. Conventions. By the coöperation of the draftsman and the builder, plans have become standardized along many lines. Various **conventions** have been introduced to do away with intricate details. Windows, doors, steel parts, and the like are merely indicated. Concrete slabs, beams, and columns are dealt with in a manner somewhat different from that which prevails in the more accurate details of machine drafting.

To introduce a complete list of conventions at this point would be futile and useless. These will be dealt with when the occasion arises. However, it will be worth our while to illustrate here what is meant by convention. If we should attempt a **conventional representation** of Window *D*, shown on Sheet 2 of the plans, we would have a drawing such as shown at a small scale on that sheet and like that shown in Fig. 1. The **accurate plan** would entail the use of many more lines and would appear as in Fig. 2. In Fig. 3 we have, for purposes of making this plan clear, a **picture** of the construction of this window.

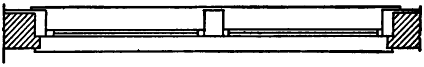


FIG. 1. CONVENTIONAL REPRESENTATION OF D. H. WINDOW *D*.

The pulley box and trim as well as the mullion pulley box are indicated here as a rectangular area. The windows are indicated by three lines blocked off at each end to indicate the sash stile. It is customary also to show the sill line on both the inside and outside of the building. The two dimensions of the window that are kept to scale are: the thickness of the wall and the masonry opening between jambs.

One of the licenses which the draftsman is entitled to is that of taking his section for his plans at a level, or different levels on the same section, which will include all the parts which he wishes to show on that sheet. He adds such **notes** and **sections** on the plan, outside of the lines of the building, as are necessary to clear up the intent of the plan. This is true of each of the plans shown on Sheets 1, 2, and 3 of the general plans.

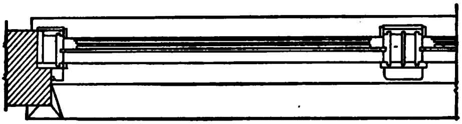


FIG. 2. ACCURATE PLAN OF D. H. WINDOW *D*.

In this figure the entire window with all its detail is indicated to scale and makes use of many more lines than the conventional representation. There are usually larger scale details of the typical windows on the other plans. Compare this with the details shown on Plate VII and with the details given in some sash and door company's catalogue and fix in your mind the general relation of the parts.

As the work of the building is studied in this book, each part will be accompanied by such plans and details as are necessary for its construction. The value of comparing these sketches with the general plans cannot be over-estimated, and the **continual contact between them and the general plans** in the mind of the student is of inestimable value and is a distinct development in itself.

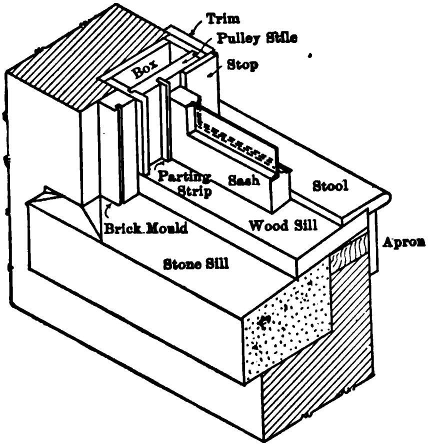


Fig. 3. Isometric View of Window *D*.

Note the names of the various parts of the window as here given. Determine the reasonable size of these parts as given in part on Plate VII and in detail in Kidder's Building Construction and Superintendence, Part II.

6. Drawing Instruments and Their Use. The instruments that the student should acquaint himself with for the execution of the sketches that ordinarily present themselves on such work as this are the **board, T-square,** the **45°** and the **30° by 60° triangles,** the **architect's scale, compasses,** and the **ruling pen** (when the work is to be inked).

The board is usually provided with two cleats at each of the two ends, which not only keep the board from warping, but also provide a smooth even-grained surface along which the T-square may slide. The T-square is composed of two parts at right angles with each other, the short, thick part being called the **head** and the thin, long part, the **blade.** If the head of the T-square is kept **snugly** along the left-hand cleat on the board and allowed to slide up and down on this guide the pencil will, when the blade is at rest, trace a horizontal line. When placing the paper on the board it is therefore important that the edge of the T-square and the edge of the paper coincide. This insures horizontal lines upon the paper, which are **parallel** with the edges of the paper

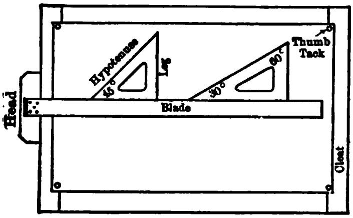


FIG. 4. DRAWING BOARD, T-SQUARE, AND TRIANGLES.

In using these instruments it is important that the draftsman keep the head of his T-square snugly adjacent to one of the cleats of the board for the delineation of all horizontal lines, and that he be careful that his triangles are similarly related to his T-square in the construction of vertical and oblique lines. Note that a combination of the angles of these two triangles will give also 15°, 75° and 105°.

To draw lines at right angles with the horizontal, i.e., **vertical** lines, the triangles are used. These also should be kept snugly adjacent to the upper edge of the T-square. The two triangles ordinarily used in drafting are the two above mentioned. The reason for calling them by the names given is because of the angles which two sides at right angles with each other make with the slant edge or **hypotenuse** of the triangle. In order to draw a line at 45° with the horizontal, it is therefore necessary to place the proper triangle with one of its short legs against the blade of the T-square, and to trace the line along the hypotenuse of the triangle. (See Fig. 4.)

The architect's scale used most commonly is the **triangular** one. It is provided with **11** scales. On one edge the scale is divided into inches and sixteenths, while the other edges are divided into scales known as the $\frac{3}{32}$, $\frac{3}{16}$, $\frac{1}{2}$, 1, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{3}{8}$, $\frac{3}{4}$, $1\frac{1}{2}$ and 3-inch **scales.**

Each of these scales has a definite meaning. For example, to say that a drawing is laid out to **¼-inch scale** means that each **¼ inch** shown on the drawing is equal to or represents **one foot** on the actual construction. The student will note that the ¼-inch scale on the rule is laid out as shown in Fig. 5, the first ¼-inch being subdivided into **12 parts** each representing one inch on the actual work. From this point on the scale, the divisions are for each foot only, and are **numbered.** Therefore, to lay off a distance on the drawing that will represent 6 feet 8 inches on the construction, the 6-foot division is placed upon the **starting point** and the pencil used to mark off on the paper the distance to inches, by counting off **8 inches** on the small divisions as shown in Fig. 5.

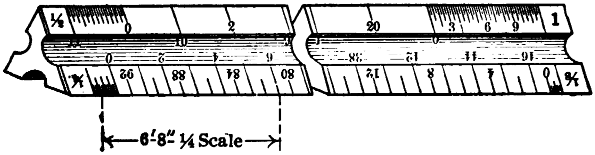


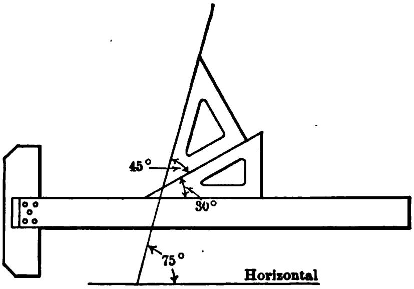
FIG. 5. ARCHITECT'S SCALE.

The underlying principle of correct scale reading is the determination of the value of divisions on the scale. In the ¼-inch scale we find that the main division is ¼ inch and that this unit is divided into 12 parts. If each unit were one foot then each small division would be one inch. Likewise in the ½-inch scale, the ½-inch unit is divided into 24 parts. Each of these divisions would therefore represent one-half inch.

The use of these instruments will become more and more simple as they are tried **over and over** again, and any further development of the art of drafting is left for the student to work out for himself, under the guidance of an instructor or advisor.

Prob. 6*a*. How would you place your T-square and triangles to draw a line making 75° with the horizontal? Sketch the position of the instruments. (See page 14.)

Solution.



Prob. 6*b*. How would you place your T-square and triangles so as to make an angle of 15° with the horizontal? 15° with the vertical?

Prob. 6*c*. A dimension on a plan drawn to $\frac{1}{8}$-inch scale is given as 67 feet 8 inches. What is the actual length of the construction on the plan?

Solution. Each foot is represented by $\frac{1}{8}$ inch. 67 feet would be equal to $\frac{67}{8}$ inches or $8\frac{3}{8}$ inches. 8 inches is $\frac{2}{3}$ of 1 foot. The actual length therefore would be $\frac{2}{3}$ of $\frac{1}{8}$ inch or $\frac{1}{12}$ inch. The total actual length of the 67 feet 8 inches dimension would be $8\frac{3}{8} + \frac{1}{12} = 8\frac{11}{24}$ inches.

Prob. 6*d*. If a line on a plan drawn to $\frac{1}{4}$-inch scale is actually $13\frac{1}{16}$ inches long, what should the dimensions for this line read in feet and inches?

Prob. 6*e*. Draw up a plan for the front concrete steps to the Lawlor Building to $\frac{3}{8}$-inch scale, giving all dimensions.

Prob. 6*f*. Reproduce Section 7, Plate I, at a scale of $1\frac{1}{2}$ inches to a foot.

7. Projection Drawing. Figure 6 illustrates one of the precast sills for the Lawlor Building enclosed in a glazed box, with the **views** one would get looking at the top, front, and side projected upon the glass sides. These three views would be called the plan, front, and side elevations and are reproduced in Fig. 7. If we trace each of the views mentioned upon the top, side, and end glasses, and then swing the top glass up, and the end glass into the same plane with the top and front, we would have the same result. In order to do this immediately, without the intervening step of tracing the view upon the glass, we would use **projection lines** as shown in Fig. 7. The two lines marked *HH* and *VV* are the hinged edges of the glass sides. As one becomes proficient with the use of projections, one omits the two **traces** *HH* and *VV*, and instead of swinging arcs, as shown, the side view is laid off by means of a marked strip of paper, or is laid out a second time for the dimensions from back to front.

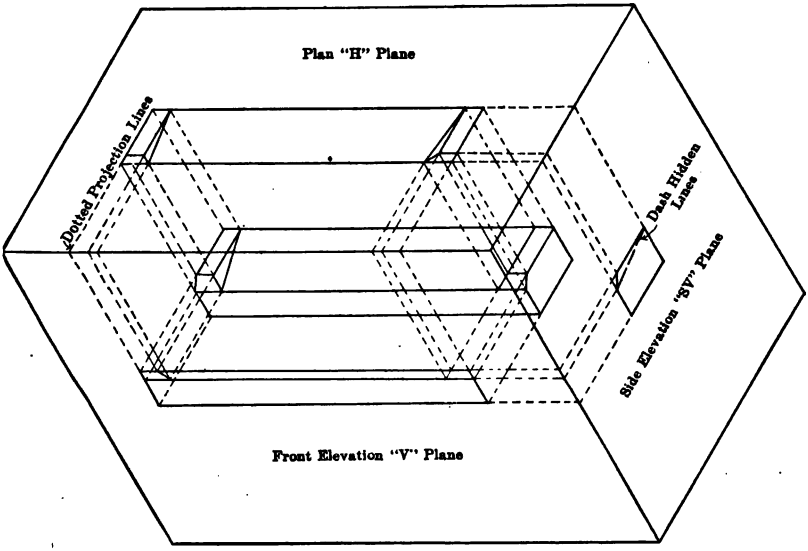


FIG. 6. PLANES OF PROJECTION.

If we took a picture of the sill from above, one from the front and one from the side, and then placed these three pictures so as to form three sides of a box so that each picture was as far from the sill as the film had been in taking the pictures we would have a similar series of views and arrangement of views to that shown here. Likewise, if we placed the sill in a glass box and traced the views we would get from above, front, and side upon the proper piece of glass, we would get such an arrangement.

In order to locate all the lines of the object in all views, it sometimes becomes necessary to show a line which in reality we cannot see. When such a line must be shown, it is indicated in **dash** lines, which indicate that the edge is hidden. The accurate use of hidden lines on a drawing make for its clearness, or may tend to cloud the meaning of the drawing. If the drawing is for the purpose of showing all **edges** and **dimensions,** the hidden lines must be shown.

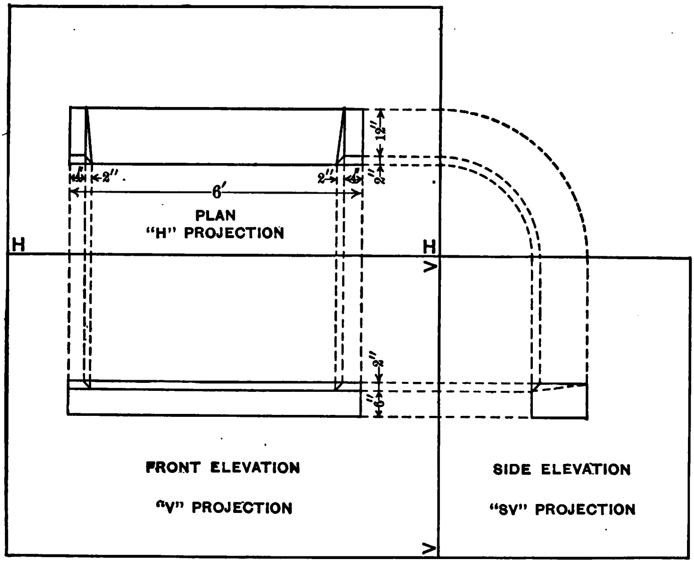


FIG. 7. DEVELOPED PLANES OF PROJECTION.

If the three views the camera took, or the three pieces of glass with the views traced upon them as explained in Fig. 6, were placed all in one plane, that is, flat upon the table, so that the top view was above and the front view directly beneath it with the side view adjacent to the front view we would get a set of developed views of the sill. All points occurring in the top view, or plan, would be directly above the same points in the front view, while they would project similarly to the side view from both the top and front views, as shown. This gives us the usual method for indicating views.

If the sheet, however, is for the purpose of showing reinforcement or some other feature, the draftsman reserves the right to omit hidden lines, at times, in order that the meaning of his drawing may not be mistaken. This is a matter of opinion, the main feature of each sheet being to enable the workman to **best build** with the **least** chance of **ambiguity.** This ability the student will develop only by contact with the actual job in connection with his draftsmanship.

Prob. 7*a*. By means of the Planes of Projection, draw a Front and Side View, and a Plan of the footing for Column No. 6. (Refer to Plate I, and use *HH* and *VV* traces.)

Prob. 7*b*. Draw three views of the same footing (Column No. 6), without using the traces *HH* and *VV* and without compasses for projection.

8. Specifications for a Vise Shop for the Lawlor Company, Austin, Connecticut.

General Description. The work included under this contract consists of the construction of the building shown on Sheets 1 to 7 of the accompanying plans: a one-story brick and concrete building 48 feet by 72 feet in size, with a coal and boiler room below grade in the east bay; concrete retaining wall for lawn and on property line; walks, and a driveway of concrete paving.

Excavation and Fill. Excavation for footing shall be carried to the depths indicated on the drawings and as much deeper as necessary to reach good undisturbed soil.

After the footings and sub-grade walls are poured, the site shall be graded to the proper level to receive ground floor paving. Any fill necessary to bring the ground to this grade shall be cinders or sand fill, thoroughly tamped, puddled, and rolled. Back-fill against footings. Grade up site for lawn and driveway; excavate for retaining wall footings. Trench for pipes as required by sub-contractors and fill over same when directed.

Walks and Gutter. The street and approach walks, as shown on the plans, shall be granolithic on cinder fill. Prepare the sub-grade and fill with cinders well tamped, to a depth of at least 8 inches. Lay 1–2½–5 stone concrete or equivalent gravel concrete slabs 4 inches thick, with integral granolithic finish made the same as hereinafter described under the heading "Paving."

The concrete is to be laid in alternate squares with the joint maintained the full depth, when the remaining squares are filled. The surface to be suitably protected and kept damp while setting up. The gutter shall be formed to suit the city authorities and surfaced similarly to the walks.

Fine Aggregate. Fine aggregate shall consist of natural sand or screenings from hard, tough, crushed rock or gravel consisting of quartz grains or other hard material, clean and free from any surface film or coating and graded from fine to coarse, with the coarse particles predominating.

Fine aggregate, when dry, shall pass a screen having four (4) meshes to the linear inch; not more than twenty-five (25) per cent shall pass a sieve having fifty (50) meshes per linear inch, and not more than five (5) per cent shall pass a sieve having one hundred (100) meshes per linear inch. Fine aggregate shall not contain injurious vegetable or other organic matter as determined by the colorimetric test, nor more than five (5) per cent by volume, of clay or loam. Field tests may be made by the architect or engineer on fine aggregate as delivered at any time during progress of the work. If there is more than seven (7) per cent of clay or loam, by volume, in one (1) hour's settlement after shaking in one hundred (100) per cent excess of water, the material represented by the sample shall be rejected.

Coarse Aggregate. Coarse aggregate shall consist of clean, durable, crushed rock or pebbles graded in size, free from vegetable or other organic matter, and shall contain no soft, flat, or elongated particles. The size of the coarse aggregate shall range from one-quarter ($\frac{1}{4}$) inch to one and one-half ($1\frac{1}{2}$) inches, not more than five (5) per cent passing a screen having four (4) meshes per linear inch, and no intermediate sizes shall be removed.

Concrete and Proportions. All concrete except as hereinafter noted shall be mixed in proportion (by volume) of one part packed cement, two parts sand, and four parts crushed stone or gravel, using stone $1\frac{1}{2}$ inches and under in size.

Concrete for walls and wall footings below grade without reinforcement, and also for retaining walls outside the building, shall be mixed in proportions of one part packed cement, three parts sand, and six parts crushed stone or gravel, using stone $1\frac{1}{2}$ inches and under in size.

Concrete for columns shall be mixed in the proportions of one part packed cement, two parts sand, and four parts crushed stone or gravel.

Proper precautions shall be taken to protect the concrete when laid in freezing weather.

Reinforced Concrete Framework. The columns shall be square, 12 × 12 inches in size; beams to be provided with tension and shear reinforcement as shown on Sheet 6; floor slabs to be 5 and 10 inches thick as shown on Sheet 2, roof slabs 6 inches thick. Build concrete curb walls for 2 skylights and 1 louvre. All slabs to be provided with ⅜-inch expansion reinforcement 24 inches on centres and at right angles to the tension steel.

All lintel beams to be of 1–2–4 concrete cast in place.

Footings and Foundations. Footings under exterior grade walls will be 1–3–6 concrete, with no reinforcement.

Tops of footings for columns shall be brought to the level of the base of the paving. They will be, with the exception of the footing for Column 7, 1–2–4 concrete reinforced.

Parapet Cap and Sills. The parapet walls above the roof are to be capped with 1–2–4 concrete, cast in place, and to have sloping wash on top, and are to be reinforced with ⅜-inch rods.

Steel sash windows will have 1–2–4 concrete sills with ⅜-inch rods for reinforcement. Wood frame windows to have precast sills of 1–2–4 concrete reinforced with ⅜-inch rods.

Concrete Finish. The parapet caps, sills, fence posts and balusters will have a rubbed finish. The lawn retaining wall will have a hammer dressed finish, even, and with all tool marks vertical.

Stairways. The entrance stairway is to be of 1–3–6 plain concrete with granolithic finish and bedded as described for walks. The stairs to the boiler room to be reinforced concrete as shown on Sheet 2, cast after the rough slab paving of the ground floor and the boiler room is in.

4-inch pockets are to be provided in the walls under stairways.

Paving. Grade site to such an elevation that when rolled and compacted it will have a level surface 5 inches below the finished floor grade of the ground floor and the boiler and coal room floors. On this surface pour a slab of concrete and straight edge to a grade ¾ inch below this finished line. This concrete shall be mixed in the proportion of one part of cement to two and one-half parts of sand to five parts of crushed stone. Before the slab has taken its initial set, add sufficient granolithic material to bring it up to the finished floor grade. In no case shall there be less than ½ inch of finish.

The material for the finish shall be broken trap rock of size known as ½ inch and under, with all material that will pass a 30-mesh sieve removed, and shall be mixed in the proportions of one part of cement to two parts of stone.

Spread the finish to the required thickness, float it and remove laitance, superfluous water, etc.

Trowel and rub smooth and hard with a steel float so as to form a dense layer and a perfect surface, free from pits, blowholes, bubbles, and other defects. Finish shall be floated once and troweled once, no further working being permissible.

Protect the finish, after the surface is hardened so as not to be injured, with a layer of sawdust, sand, bagging, or other suitable material, and keep it thoroughly wet for ten days.

The toilets, vestibule, vault, and office portions to be finished with similar materials placed as described above, upon the structural slab.

Forms. Provide forms which will be strong enough to sustain the pressure of the concrete when wet. They must be tight, smooth, and should be oiled before the concrete is deposited in them.

Tile. The interior partitions as located on the slabs around the office, stairway, toilets, vestibule, and vault shall be of hard-burned terra-cotta tile as manufactured by the National Fire-proofing Company, or equal, scored on both sides and 4 inches thick.

All tile work to be laid in mortar composed of one part thoroughly slaked lime putty, two parts Portland cement, and six parts of clean sand, and shall be thoroughly mixed. No mortar to which the cement has been added shall be used after it is more than one hour old. All mortar shall be uncolored.

Both sides of all interior tile partitions, except as noted, will be plastered, and all plaster is to be mixed of one part cement, three parts sand, and one-quarter part slaked lime paste; the first coat to contain enough cattle hair for a good bond.

Plaster to be applied in two coats to finish ¾-inch thick over the face of tile and to be troweled to a smooth even surface.

All exposed corners of plastered tile shall be protected with approved metal corner beads.

Brickwork. Use brick of a uniform dark red color and sand struck, sound, hard, and well burned, for all of the brickwork. Where exposed on the exterior, the sand struck brick shall be selected. No light or salmon brick shall be delivered at the site, or used in any part of the work.

All brick shall be wet before being laid in warm weather, but kept perfectly dry in freezing weather.

All brick shall be laid in mortar composed of one part of Portland cement to three parts of sand, tempered with not exceeding one part of the best slaked lime paste. The proportion of cement is not to be varied.

All brick shall be laid in a full bed of mortar and all joints of each course shall be well flushed with mortar until solid, before another course is laid on top.

Provide the necessary material to protect the walls from the weather, if stormy, and at all necessary times.

Concrete Blocks. The partition between the boiler room and the coal room is to be of 8-inch concrete blocks (smooth) laid in the same mortar as the brickwork.

Wood Frame Partitions. The office walls on the north and west sides are to be built of a 2 × 4 studding covered with "self-sentering" and plastered as described for tile.

The sash shall be fixed and of a design suitable to the owners. The contractor will supply a detail of the type he proposes to erect, to the owners.

All the sash in this partition shall be glazed with *AA* clear sheet glass.

Steel Sash. The steel sash will be rolled steel sash as manufactured by the Detroit Steel Products Company, or equal. The sash will be of the side-wall type fitted with pivoted ventilators, located as shown on the elevations of the building, and operated with cam latch and stay bar. The mullions of the sash shall be of the "T" bar type.

All sash shall be primed with one coat of oxide paint before delivery.

Glass. All steel sash shall be glazed with factory ribbed glass, with ribs vertical and on the inside. Putty for exterior shall be Baker's standard specification putty.

Pipe Rail. The pipe railing on the stairs to the boiler room shall be of a standard steel $1\frac{1}{4}$-inch pipe with malleable fittings to fit $1\frac{1}{2}$-inch pipe-posts.

Posts shall be made of either one continuous piece or two pieces and threaded-in fittings. In no case shall the posts be made of two pieces with slip joints pinned together.

All longitudinal railing passing through fittings shall be thoroughly pinned to same to give a rigid connection.

Posts shall be grouted in connection with the concrete work and have flanges pinned at these points.

Flanges on concrete shall be fastened by expansion bolts.

The dimensions of railing shall be 16 inches from the foot of the posts to center of the first rail, and 16 inches from the center line of the first rail to the center line of the top rail.

All work to be done in a workmanlike manner, posts level and true, and joints rigid.

Posts for pipe railing shall be cut and made up to schedule in the shop. Rails shall be ordered and sent to the job in random lengths and cut and fitted on the job.

Wood Sash and Frames. Exterior windows in the south and east elevations shall have 2¾-inch double-hung sash of clear white pine, and box frames of white pine or cypress with hard pine pulley stiles and parting beads. Frames to be complete with weight-pockets, steel axle roller-bearing pulleys with 2½-inch diameter sheaves grooved for chains, and bronze plated sash chains. To be glazed with ¼-inch polished plate glass.

The opening *C* on Sheet 2 will be similarly treated.

The sash and frames shall have a priming coat of white lead and oil before shipment. All glass to be well bedded in putty.

Wood Doors. The exterior wood doors and the inner door at the office entrance shall be of second quality white pine or first quality cypress stock, free from sap, knots, and shakes, and thoroughly kiln dried, and of sizes and dimensions shown on plans. The upper panels will be glazed with ¼-inch polished plate glass.

The doors to the toilets and to the vault shall be of fir stock as detailed, 1⅜ inches thick, and hung in flush wooden frames with stops fastened to wood lugs in the tile work.

All wood doors shall be primed with one coat of white lead and oil before shipment.

Cinder Saddles. On top of the surface of the roof slab sufficient cinder fill shall be placed to give the required saddles as specified on the roof plan. This cinder fill shall be a compound of good soft coal cinders mixed with cement in the proportion of 10 to 1. A dry mixture shall be used so as to have no surplus water to soak into the roof slab. It shall be carefully screened and rolled to the grades and pitches shown and given a coat ⅝ inch thick of a mixture of four parts of sand to one part of cement floated to a smooth surface to receive the roofing.

Light Iron. The shipping door shall be provided with 12-inch 20.5-pound channel jambs securely anchored into the brickwork by ½ × 10-inch anchors. The sill shall consist of a ½ × 12-inch checkered steel plate riveted to a 2½ × 2 × ½-inch angle guard as shown. This should be anchored to the concrete sill with ⅝-inch J-bolts cast in place.

The contractor shall build the cast-iron frame and door for the cleanout in the base of the stack, the ash door and the checkered steel plate and angle frame for the coal chute into place.

The iron ladder leading from the wind of the boiler room stairs to the boiler room shall be supplied and built into place by the contractor.

All iron work shall be complete with necessary bolts, washers, anchors, plates, and other fittings to make a thorough job.

All steel and iron work to receive one coat of red lead and oil before delivery.

The roller door for the shipping opening to be of an approved type and guaranteed.

Roofing. The roof covering shall be J. M. asbestos built up roofing provided with the necessary cap and base flashings. The contractor will furnish a smooth even surface for this work. The roofing contractor is to pay particular attention to the nature of the roof surface before applying his roofing, and any defects in smoothness, pitch, or quality of the surface shall be reported to the contractor at this time in order that they may be made satisfactory before the roofing is laid. No alleged defects in the roof surface on which the roofing is laid will be accepted as an excuse for a defect in the roofing after it is in place.

Flashings. The roofing contractor will cap the parapets with a J. M. cap flashing, cemented on and guaranteed. All vertical surfaces extending above the roof are to be similarly treated. The cap flashing of the chimney is to be 24-gauge Toncan metal, or equal, built in by the general contractor.

Skylights. There will be two hipped skylights and one hipped louvre anchored on curb walls, as shown, with ⅝-inch J-bolts. They shall be made of 24-gauge galvanized Toncan metal, or equal, and shall be provided with bars rebated for ¼-inch ribbed wire glass 12 inches wide in a single length. They shall have galvanized Toncan, or equal, condensation gutters to discharge on the roof surface. The frames to be reinforced with steel ribs.

Office Floor. The office floor shall have a plain linoleum of good quality (Battleship) cemented to it.

Painting. The owners will supply the material and labor for all painting.

Sub-Contracts. The plumbing, heating, and painting will be sublet by the owners and are not a part of this contract. It has not been intended to show all the inserts for pipe hangers and square or rectangular holes for all pipes which pass through the floor.

The sub-contractors shall, when erecting their pipes, place pipe sleeves on them as follows:

Plumbing. — All water pipes through walls and floors.

Heating. — All pipes through walls and floors.

All sleeves through walls shall be flush on each side. All sleeves through floors shall project 2 inches above the finished floor and shall be flush on the ceilings.

The general contractor shall grout in place all pipe sleeves and all pipes not requiring sleeves. He shall also place all machinery foundations where and of the size required, providing anchors for the wood blocking that may be required for machine cushions.

Any holes which are not used shall be filled with sawdust or shavings and covered with granolithic finish on both the floor and ceilings.

The general contractor shall do all cutting, and patching of walls, floors and ceilings, and all masonry work, including drilling for expansion sleeves.

The general contractor will provide boxes for all cleanouts and traps in the drainage line. These are to be filled with sawdust or shavings and coated with granolithic finish, marked to the size and shape of the box, for future cutting.

Prob. 8*a*. Tabulate the various mixes of concrete specified for the Lawlor Building with relation to the part of the structure so composed.

Prob. 8*b*. On page 19 of the specifications, 4-inch pockets are called for in the walls to support the stair slab. Draw an elevation to ½-inch scale of the North wall, looking north, showing this pocket.

9. Problems for Review.

Prob. 9*a*. What is the flange width of a 10″-15# channel? (indicated 10″ ⊏15#). A 15″ ⊏33#? A 12″ I 31.5#? A 15″ I 42#? (Consult "Elements of Sections — Structural Shapes" in the "Carnegie Pocket Companion.")

Prob. 9*b*. What is the thickness of the web of a 12″ I 31.5#? Draw a detail of the section of such an I-beam to 3-inch scale. (Consult "Beams, I-Beams . . . profiles, weights and dimensions" in "Carnegie.")

Prob. 9*c*. By an examination of Plates V and VII, draw a plan and two views to a ¾-inch scale of the two 12″ ⊏20.5# jamb guards for the shipping door in the East wall.

Prob. 9*d*. Draw a plan and section of the angle sill-guard to 1½-inch scale.

Prob. 9*e*. Draw a plan and double elevation to ¾-inch scale of the entrance door to your home. (See Plate VII.)

Prob. 9*f*. Reproduce the plans shown on Plates I and II to ¼-inch scale.

CHAPTER III

SIMPLE FOOTINGS

10. Footings. The first part of the building to go in place is the footing plates or slabs. These are the parts that are cast into the trench or form, upon which the foundation walls and columns, or column piers, rest. These plates or slabs are shown in section on Sheet 1 of the general drawings, and if we take section 5–5 as a sample, we will have the construction shown in Fig. 8.

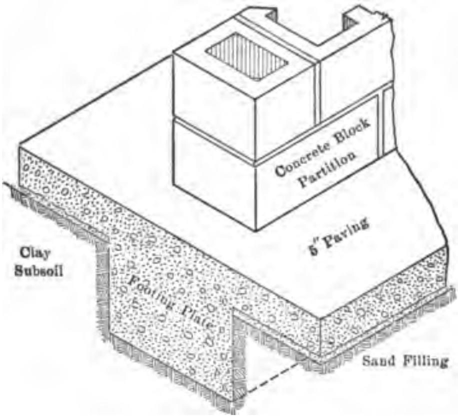


Fig. 8. Isometric of Section 5–5, Plate I.

In an isometric drawing all the lines which are in reality parallel are shown parallel, as contrasted with perspective where the attempt is made to reproduce the object as the eye or the camera would depict it. The advantage of this type of drawing is that one can combine all the views in one and by making all the parts to a convenient scale the drawing may be used as an assembly construction drawing. In this type, then, all the parts will appear in their true scale.

Compare this with the conventional representation of this footing on Plate I and note the section located outside of the lines of the building, which indicates its construction. Sections 1, 2, 3, 4, and 6 are similarly indicated.

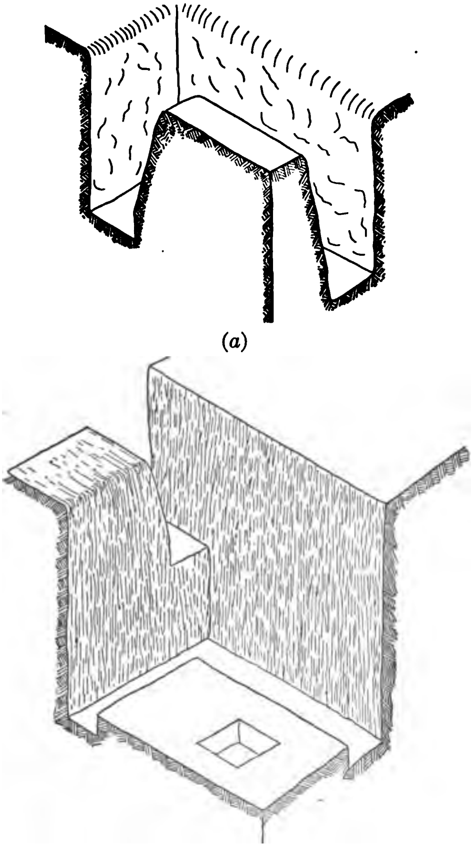
11. Excavation. Before these footing slabs may be cast, the soil must be removed, or **excavated,** to the level of the bottom of the pavings which are to rest upon it. The **area** is then **trenched** at the points where the various footings are to be, and if the soil is of a nature which allows it to **bank** easily without the use of protection against "cave-ins," the excavation will look like Fig. 9.

All soils, however, do not bank, and it is necessary to take some precautions against the tendency to flow. Various methods are used for this. In the case of our building it would be possible to **slope** the sides of the bank sufficiently to overcome this tendency to cave in. If the adjoining property owner has a building on the line to which our building must be built, this cannot be done without danger of failure of his building. In this case it would be necessary to **drive** close **sheeting** on the bank side of the excavation or to **brace** the excavation by lining it as it is made, and bracing it to the adjoining wall of earth or to stakes. In places where the excavation is **deeper than 8 ft.,** it is usually better to **support the bank** than to slope it. These methods are all worthy of the student's consideration and are sketched in Figs. 10, 11, and 12.

In the investigation of the soils on which our building is to be built it was found that the soil was stable and banked safely and well. In this case the walls of the excavation should be **cut to the neat size** of the building and footings. They may then be used as one side of the form, thereby effecting a considerable saving in material and labor. A reference to Fig. 9 at this point will explain the meaning of "cutting to the neat size."

(Perform Jobs Nos. 12 and 13, Vol. II.)

The **quantity** of excavation is ordinarily calculated by



(*a*)

(*b*)

Fig. 9. Isometric Views of Excavations for Footings.

Some clay soils are sufficiently stable to stand up without bracing for reasonable heights. When such are encountered the excavation may be trimmed to approximately the true size shown on the drawings. These soils sometimes allow the casting of footing slabs without the use of wood forms. This effects quite a saving. It is worth while knowing what the soil will do before proceeding with the estimate.

(*a*) Northwest Corner of Building.

(*b*) At footing for Col. No. 7.

cubic yards of earth removed. The **accessibility, depth, nature of soil,** and **disposition** of the excavated earth determine the unit price per yard. In some places the soil is of such a nature that it is possible for the teams or trucks to run down into the excavation on an inclined plank ramp. This reduces the cost of the work materially over the old hand method which necessitated the handling of the material many times. The earth was usually thrown upon a banked shelf from where it was again raised to the grade. It then had to be reshoveled into the wagons or trucks. On large excavations where the soil is reasonably loose a **steam shovel** can be used. This is usually placed down in the excavation and loads directly into the carriers. The **size** of the job must be considered when the decision is to be made as to which method should be used. In our building, because of the nature of the soil, it will be possible to use the first method described above in the three west bays

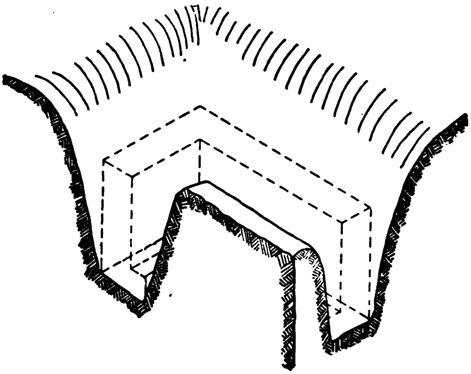


FIG. 10. SLOPED BANK EXCAVATIONS.

In this case it was necessary to slope the bank to such an angle that the soil would be stable against a cave-in. When such soils are met with it is necessary to estimate the additional excavation, the use of forms on both sides of the wall, and the backfill required to bring the soil in contact with the concrete after the work is cast. The difference in cost of this over that shown in Fig. 9 is considerable.

of the excavation, but, owing to the limited size of the boiler and coal room excavations, the hand method probably is the best one to use for this work. A careful examination of the elevations of the various footings will prove the advisability of such a method.

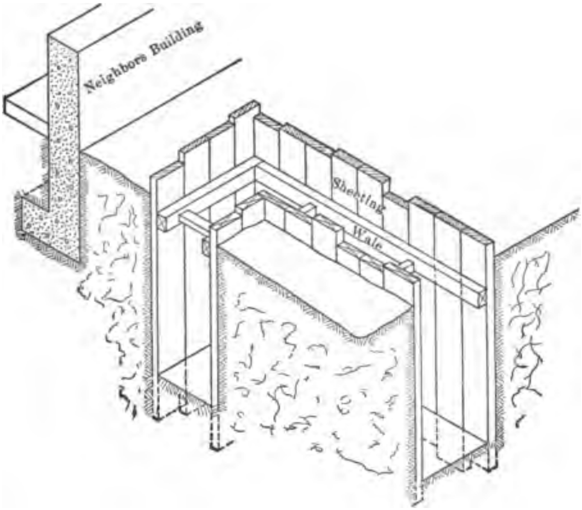


FIG. 11. SHEETING EXCAVATIONS.

This method is usually employed where the soil is very unstable, such as sand, and in cases where the walls are deep and wide. The sheeting is made up of tongued and grooved or splined planking about 2 inches thick. The wales are usually 4 × 6 or 6 × 6 timbers, and are spread by the use of 4 × 4 spreaders. This method is often followed where a footing is close to another building foundation.

Hand excavation necessitates the loosening of the earth. To do this a **pick,** a **mattock** or a **plow** is used. The pick usually is confined to trench and footing plate excavations because of the limited space for work. The **mattock** is mostly used as an **accessory to the pick,** inasmuch as it is commonly employed for plumbing banks and leveling surfaces. In open general excavations, such as are always found in basements of this type, the plow is the most efficient tool to use. If the excavation is large enough and does not confine the plow to a short section it is very economical.

(*Perform Job No. 11, Vol. II.*)

The loosened earth must then be shoveled either directly into **wagons** or into **wheelbarrows.** These are used to haul the earth to some dump. The **shovels** ordinarily used are the **square point** or the **round point** with either long or short handles. (Fig. 13.) If the lift is short the man can work much more efficiently, and platforms for passing should be arranged to take advantage of this. The square point shovel is used more frequently than the round point, which is usually confined to the working of stiff clay.

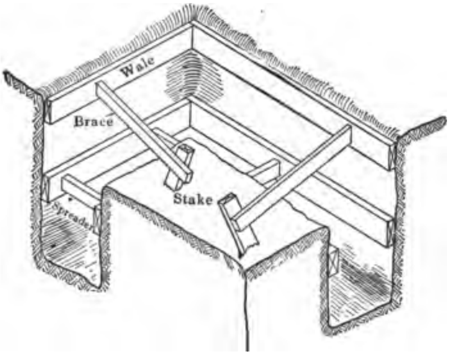


FIG. 12. BRACING EXCAVATIONS.

Where the soil is a mixture of sand and clay or is a loosely cemented gravel it is often possible to do away with the sheeting, and to substitute 2 × 12 or 3 × 12 plank wales separated by 4 × 4 spreaders in the trench and held in place by 4 × 4 braces secured to 3 × 4 stakes driven into the ground before the trench is started and sufficiently far away to prevent a cave-in. This material is removed as the casting advances. In soils of this kind it is wise to wet them down well before casting, as they absorb a large amount of water and might weaken the concrete by a removal of the mixing water.

The use of wheelbarrows for hauling is discouraged where teams are available. The fact that an ordinary **wheelbarrow**

load is about $\frac{1}{16}$ **of a cubic yard** in the settled bank easily proves this. The use of wagons for hauling is almost universal unless some more extensive plant is used. Wagons may be either of the **slat, bottom dump,** or **rear dump type.** These are illustrated in Fig. 14.

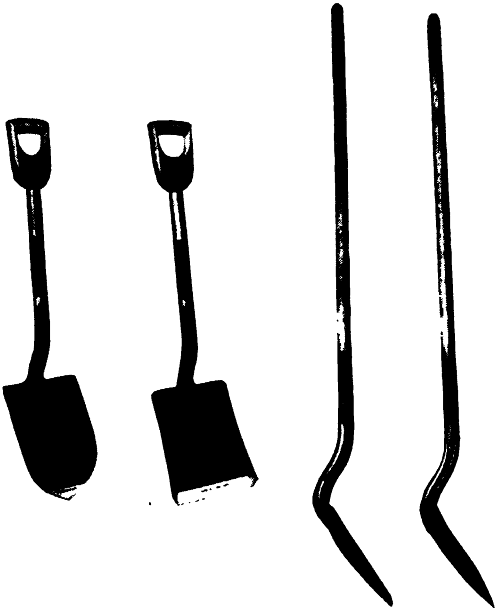
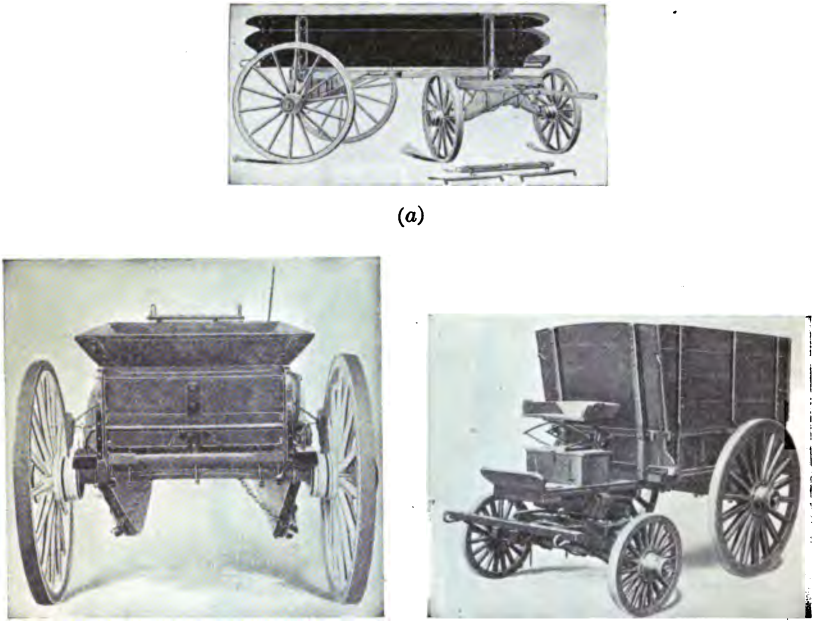


FIG. 13. WYOMING RED EDGE SHOVELS.

The two types of shovel used in excavation are the round point and the square point. The former is the most useful in the loosening of picked soil, while the square point is better for the removal of loose soils and the truing up of a trench or excavated area. The long handle shovels are for positions where a trench is deep and rather narrow and in places where the throw to the platform or wagon is high.

The handling of teams for hauling must be studied with the idea of **economy of operation.** If the haul is short, one wagon is left on the job to be loaded while the team and driver take the other to the dump. This keeps the team working at its maximum efficiency. If the haul is longer, the number of teams that can be used to best advantage is determined by its length. **One wagon** should always be **loading**



(a)

(b) (c)

Fig. 14. Columbia Wagons.

The old type of slat dump wagon, (*a*), is still in use today. The parts are all so arranged upon the running gear that they are easily removable. To empty this type the end gate is first removed, and then the sides. The bottom, which is composed of narrow scantlings, is removed piece by piece by turning each over, thereby removing the soil. The object in any of the types is to avoid hand labor in shoveling. The modern bottom dump wagon, (*b*), is equipped with gates which can be dropped down on hinges by means of chains connected with some type of wheel and axle device. The rear dump wagon, (*c*), is provided with a removable end gate and is swivelled on the rear axle and fastened by a pin at the front of the box. Being slightly overbalanced it can readily be tipped back by a lift at the front. As the wagon pulls away the soil leaves.

and a **second team** should arrive in time **to take its place** when ready. If the haul is long it is not so important to load rapidly as the teams need a short rest after each trip.

If the excavation is of a size that will justify the expense of a steam shovel for the removal of the earth, it is by far the most economical method to use. Fig. 15 shows the common type of shovel used. The ordinary rigs of this type require the **services of two men,** the cranesman and the engineer. Shovels are **rated** by the capacity of the bucket **in yards per scoop,** their output usually being limited by the hauling **arrangement** used. The economical use of shovels is a study

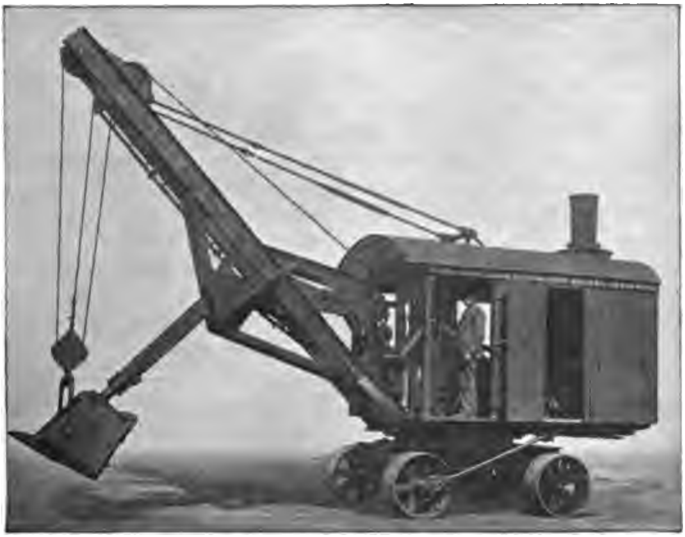


FIG. 15. THEW STEAM SHOVEL.

The use of the steam shovel for large excavations is very common. The equipment consists of a steam boiler mounted on a truck which drives a small engine which operates a drum. The shovel is at the end of a boom which is controlled from the truck. The common shovel is merely a steel box equipped with a cutting edge and a movable hinged bottom.

in itself, and it is well worth the student's while to study them further from catalogues, reports, and by observation.

Prob. 11*a*. If the soil in the vicinity of this building is stable and needs no sheeting, and 12 inches are allowed outside the wall for form work, how many cubic feet of excavation will be necessary to place the center bay of the west wall?

Solution. Depth of excavation equals 62 − 56.67 or 5.33 feet.
Width of excavation is 12 + 24 inches = 3 feet.
Volume of excavation per foot of wall = 5.33 × 3 = 16 cubic feet.
The wall in this section is 16 feet (Plate I).
Total excavation equals 16 × 16 cubic feet = 256 cubic feet.
This is expressed on estimate sheets as follows:

Description	No. of units	Length	Width	Depth	Quantity	Cubic yards
Excavation Center Bay West Wall	1 ×	16 ×	3 ×	$5\frac{1}{3}$ =	256 c.f. =	9.5

Prob. 11*b*. Assuming that no forms are required for the footings of Columns 1 to 6, how many yards of excavation will be required for them? Express in estimate form as in Problem 11*a*.

Prob. 11*c*. As forms are required for both sides of the wall separating the boiler and coal rooms from the rest of the building, how many yards of excavation are required to make room for it?

Prob. 11*d*. How much excavation will be required to make room for the driveway?

Prob. 11*e*. Exclusive of footing plates or slabs, how much excavation is there for the entire building proper?

Prob. 11*f*. How much additional excavation is necessary to build the retaining wall on the property line?

12. Information Concerning Tools Used in Excavating.

Tools used in excavating, and relation to various kinds of earth.

(1) **Square pointed shovel,** used for:

(*a*) All kinds of earth that has already been loosened by pick, plow, or some mechanical equipment. Examples, plowed loam, clay, cement, gravel, sod.

(*b*) Earth that is already loose in its natural state. Examples, sand, gravel, and top soil.

(2) **Round pointed shovel,** used for:

(*a*) Earth easily shoveled from its natural state by pressure of foot on shovel.

(*b*) Excavating under water in clay, some hard-pan and quick sand.

(*c*) Fine materials that have been compacted, such as sand, fine stone, or slack-coal in cars.

(3) **Pick.**

Used to loosen any kind of earth, some stone and gravel impossible to loosen with shovels, spades, or mattox.

(4) **Mattock.**

(*a*) Used in cutting roots, straightening sides of excavated pit or foundation.

(*b*) Some earth of a sticky nature.

(5) **Spade.**

(*a*) Especially used in tough clay, hard-pan, and earth not possible to shovel.

(*b*) Principal use in digging narrow, deep ditches.

(*c*) Various types — tile spade, etc.

Prob. 12*a*. If the soil encountered in the vicinity of this building is compact yellow clay, make a list of the tools required to complete the excavation. Price this list by conference with a hardware dealer. Who would supply these tools?

13. Swelling of Earth.

(1) **Various kinds of earth and increase in volume when moved from natural state.**

(*a*) Clay, hard-pan — approx. $\frac{1}{2}$.
(*b*) Loam, light clay and gravel mixed — $\frac{1}{3}$.
(*c*) Sand and gravel — (**Remain almost same**).

(2) **Settling of various fills.**

(*a*) Fills made of earth with great increase of volume settle most and quickest.
(*b*) Fills made by washing sand and gravel into place settle very little.

Note.— The amount of settlement of various fills cannot be accurately estimated, only under stated conditions. It can be safely said that when made into an embankment earth gradually subsides, shrinks, and settles into less bulk than it previously occupied.

(3) The following are approximately the **percentages of shrinkage of earth** taken from the cut and placed in the fill without mechanical rolling, tamping, etc

Gravel or sand........................	about	8	per cent
Clay................................	"	10	"
Loam................................	"	12	"
Surface Soil..........................	"	15	"
Puddled Clay........................	"	25	"

One cubic yard of rock increases or swells when replaced, as follows:

In loose heaps................................	1.9	times
Carelessly piled..............................	1.75	"
Carefully piled................................	1.6	"
Scabbled stone. (No mortar joints.)...............	1.5	"

(*See also "Ransome Book."*)

Prob. 13*a*. If a yard of clay is removed from the excavation and filled into another area, what volume will it occupy in this area?

Solution. From (1*a*) Art. 13, clay increases in volume about 50 per cent.

Therefore, loosened volume of 1 cubic yard = 1.5 cubic yards.
From (3) Art. 13, clay shrinks about 10 per cent upon replacement.
Therefore, 1.5 cubic yards will occupy 0.9×1.5 cubic yards = 1.35 cubic yards in the fill.

Prob. 13*b*. Work out a table for Clay, Loam, and Sand, giving the "fill" volume of each, per cubic yard in the bank.

Prob. 13*c*. If a rear dump wagon carries 1 cubic yard of excavated clay, how many loads will be required to remove the soil from the excavation of this building? How many yards will the soil occupy in the dump?

14. Plant. The excavations complete, the job is ready for concreting. This operation can be varied in expense by the way in which the materials are handled. When they are delivered to the site, they should be placed in a spot where they will be **most** easily **accessible,** and from which they will necessitate the **shortest haul** for mixing. They must not be placed in a location where they can become an obstruction to the progress of the work. When near the mixing board or mixer, which must be so placed that it will command access to all the footings, they sometimes present quite a problem. This **feature** of the work **must be studied** by the superintendent or foreman, and the measure of success with which he approaches this part of the work will determine whether he is capable and efficient or not.

Fig. 16 shows a layout of the plant for this building. Other schemes could be evolved for just the same efficiency as this, and the student should work out some of these for criticism.

One of the matters of prime importance for the successful and economic handling of materials, together with the proper location, is the **storage of materials.** A definite effort should be made to insure **sufficient space** for storage, so that delayed deliveries will not necessitate a shutdown. It is approximately true that the amount of **stone** used will be **twice the** quantity of **sand,** and the **sand** will be **double** that of **the cement.** In laying out the plant, therefore, early study and care should be exercised to insure proper routing and disposal of these materials.

Parallel with, and just as important as the provision for adequate space, is the **care** of the material **on arrival** at the job. **Cement is** just as **susceptible to rain water** and ground or air moisture as it is to the water for mixing. It should always be stored in a **weather-tight** building (Fig. 17) raised from the ground about 6 or 8 inches. The cement that is out for immediate use should be placed upon a dry plank and with a water-tight covering, if the air is damp, or the weather threatening.

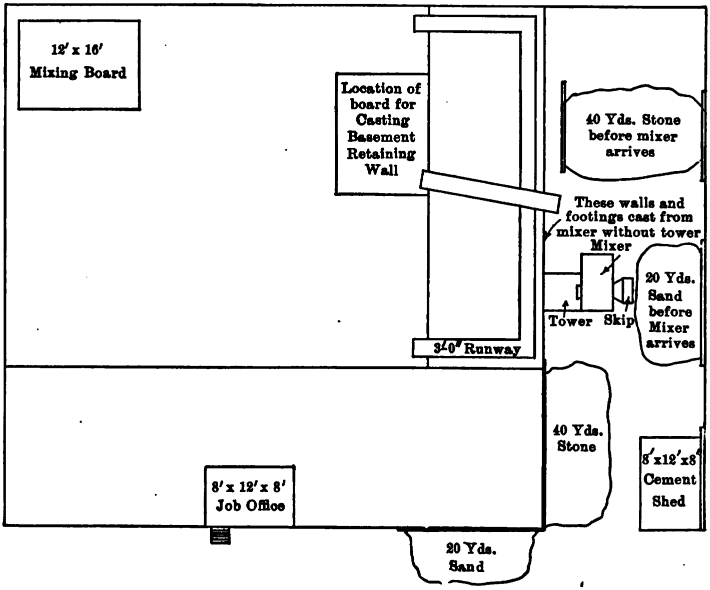
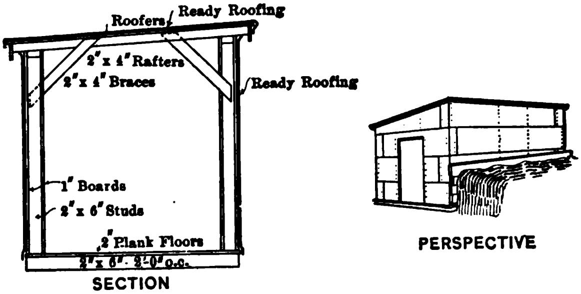

12' x 16'
Mixing Board
Location of board for Casting Basement Retaining Wall
40 Yds. Stone before mixer arrives
These walls and footings cast from mixer without tower
Mixer
20 Yds. Sand before Mixer arrives
Tower
Skip
3'-0" Runway
40 Yds. Stone
8'x12'x8' Cement Shed
8' x 12' x 8' Job Office
20 Yds. Sand

FIG. 16. LAYOUT OF THE PLANT FOR THE ERECTION OF THIS BUILDING.

The correct location of the storage piles of the material, and the equipment for their incorporation in the building is a definite study. This will depend upon the method which is to be used for the various parts of the structure and the quantities that should be handled at any one time.

Contractors have been in the habit of caring for their cement for some time. They have discounted the **care of the aggregate,** however, and it is not until very recently that the importance of care in the storage of this part of the concreting material has been actively recognized. Stone, when arriving on the job, or at least before it is used, should be clean; and it usually is. To dump it upon the ground where it will become mixed with dirt and deleterious matter is wrong. It should be discharged either upon a platform of planks or upon a deep layer of sand. The same can be said for the fine aggregates, or sand. These two materials have been handled too carelessly in years past, and the importance of **cleanliness** cannot be overemphasized.



SECTION

PERSPECTIVE

FIG. 17. CEMENT SHED.

The large percentage that the cost of the cement bears to the cost of the concrete is in itself sufficient reason for its proper protection. The size of the shed must be determined by the most economical store of cement that should be on hand at any time. This should be studied with the idea in mind that at no time should it be entirely depleted or of excessive size. It should also be designed to allow of the least labor in filling or emptying.

(*Perform Jobs Nos. 14, 15, and 16, Vol. II.*)

When concrete is **hand-mixed,** a water-tight platform is used, which should be large enough for **four men** to work conveniently with shovels. (Fig. 18.) It is built of **2-inch planks,** tongued and grooved, splined or specially moulded, as shown in Fig. 19, to prevent the leakage of water. These planks are **cleated** with 2 × 4's on edge, the end cleats provided with steel eyes for hauling the platform from place to place. Some contractors use steel sheets nailed upon a plank bottom. Three edges of the platform should have

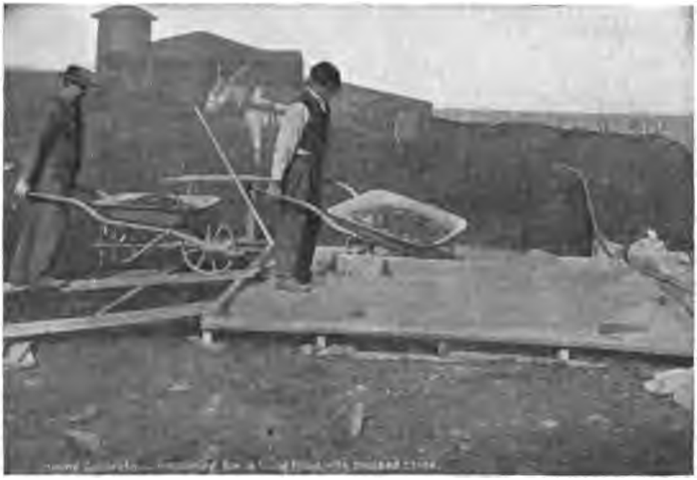


FIG. 18. MIXING PLATFORM.

This must be so located that it will be convenient to the material piles and to the point of casting. It is sometimes very desirable to have it so close to the point of casting that the mixed materials can be shoveled directly into the forms from the platform. Hauling eyes permit it to be drawn from one place to the other with a horse. It must be watertight and should be level, so as not to impair the action of the water in the concrete. (*Courtesy Portland Cement Association.*)

2 × 2 strips nailed along them to prevent the loss of material in mixing.

Another small but important part of the plant for hand mixing is the **measuring box.** It is usually made of 2 × 12 planks, in capacities of from 1 to 4 cubic feet, and is bottomless. The two sides are projected by, and form the handles. (Fig. 20.) Sometimes the measuring box is dispensed with and a definite relation is established between the wheelbarrow load and a cubic foot. Roughly, the ordinary **wheelbarrow** may be said to **hold 2 cubic feet,** and the **cubic foot is about 7 shovelfuls.**

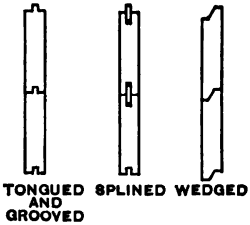


FIG. 19. PLANK MOULDING.

One of the very occasional defects of concrete is that produced by leaking forms, and is prevented by the use of a moulded lumber such as shown in this figure. In addition to making the form tight these moulded planks add stiffness between cleats, another vital necessity for good concrete work.

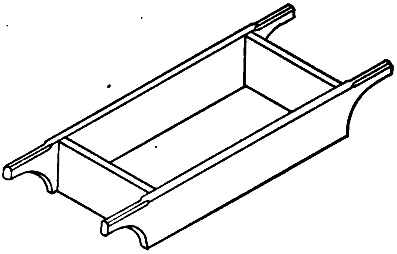


FIG. 20. BOTTOMLESS MEASURING BOX.

Careless proportioning of concrete has been responsible for many poorly constructed concrete buildings. Where a mix is to be subjected to extreme conditions of stress or water pressure the materials are carefully measured for volume before they are incorporated into the mix.

Prob. 14*a*. How many board feet of lumber are required to build a mixing platform 10 × 12 feet? One board foot is a piece of lumber 12 × 12 × 1 inches.

Solution. A 2 × 8 plank, therefore, would have $\frac{2 \times 8}{12}$ board feet per foot of length, and if it were 12 feet long, each plank would have $\frac{2 \times 8}{12} \times 12 = 16$ board feet.

Prob. 14*b*. How many board feet of lumber will be required to build a measuring box with a capacity of 4 cubic feet?

Prob. 14*c*. Make a set of plans to ¼-inch scale, including a plan, two elevations, and a cross section of a cement shed to accommodate one minimum carload of cement.

Prob. 14*d*. Make a bill of materials for this building. How many board feet of lumber are required?

15. Cementing Materials. The materials which give strength to the concretes, and which act as binders, are called **cementing materials.** These are commonly divided into two classes — **hydraulic** and **non-hydraulic.** The former will set in air or under water, while the latter will not harden under water. Professor Hool classifies the structural cementing materials as follows:

Hydraulic
- Hydraulic lime.
- Puzzolan cement.
- Natural cement.
- Portland cement.

Non-hydraulic
- Gypsum plasters.
- Common lime.

We will concern ourselves at this time with **natural** and **Portland cement** only, leaving the non-hydraulic material until a later chapter on "Finish," and the other hydraulic cements for the student's further study.

The former of these two cements was used extensively previous to the introduction of Portland cement, and its use at that time was due to the fact that some one found a **natural rock,** which, when ground, after being burned at a temperature of from 900° to 1300° F., would make a substance which did not slake as lime does, but which hardened or set upon the addition of water, due to the formation of calcium silicate. Following up the success of this product, the possibility of manufacturing an **artificial substance** which would act similarly, was sensed, and so Portland cement became a commercial product and a competitor of natural cement.

Natural cement, made from a rock occurring in nature which had the combination of clay and limestone (argillaceous limestone), was made in as many localities as afforded the rock. Unfortunately, however, its composition and characteristics varied widely, even in strata of a single formation or deposit. It is adapted to many uses, however, but its relatively low strength at an early age limits its use to structures where heavy loads will not come upon it for several months; in places where **mass and weight,** rather than early strength, are essential, as in dams, abutments, foundations and many underground structures, it is distinctly useful and cheap.

Portland cement, on the other hand, being an artificial product, has its component parts controlled, and it can be expected to remain uniform in general characteristics wherever it is manufactured. This has been done by setting **standards** for this work, and all companies manufacturing Portland cement follow them carefully. It is made by **finely pulverizing** the clinker resulting from the burning of a **definite artificial mixture** of siliceous, argillaceous and calcareous materials to a point just short of fusion.* (Fig. 211, Appendix.) Small portions of iron, magnesium, alkalies of potassium and calcium, and sulphur are found in most Portland cements. It is by far the most important cement used today. It **acquires** its **strength rapidly** and is adapted to all types of construction where **strength** and **wear** are necessary. It is now used exclusively for reinforced concrete construction.

It will be interesting at this time to compare the characteristics of these two cements and the following Table makes this comparison:

* Siliceous	containing	silica SiO_2
Argillaceous	"	alumina Al_2O_3
Calcareous	"	calcium or lime

TABLE II *

COMPARISON OF PORTLAND AND NATURAL CEMENTS

	Natural	Portland
Raw material	Natural rock	Artificial mixture
Type of kiln used	Vertical, stationary	Slanting, cylindrical, revolving
Calcination temperature	Low, but variable	Relatively high
Chemical composition	Not under control	Controlled within narrow limits
Color	Yellow to brown	Bluish or steel gray
Specific gravity	2.7 to 3.1	3.1 to 3.2
Rate of set	Relatively rapid	Relatively slow
Strength	Low, at early age	Relatively high
Degree of grinding	Usually rather coarse	Relatively fine
Soundness	Will not stand steam test usually	Required to stand steam test
Mortar mix	1 : 2	1 : 3
Concrete mix	1 : 1 : 2	1 : 2 : 4

Prob. 15*a*. The specific gravity of a substance is defined as ratio of its density to that of some standard substance. The standard usually employed is water at 4° C.

To determine the specific gravity of a substance insoluble in water we would weigh it in air, then immerse it in water and weigh it again. The difference in weight would be the weight of water it displaced. The ratio of the weight of the substance to the weight of the displaced volume of water would be its specific gravity.

Prob. 15*b*. Determine the specific gravity of a piece of coarse aggregate.

16. Testing the Quality of Cement. In large operations the cement is **tested for quality** at the mill and checked up on the job. These tests are elaborate and require skilled manipulation. However, simple field tests may be used as a precautionary measure to determine if the cement is safe to use. Among these the test for time of setting is most useful, and also the boiling test. These will determine the departure from normal quality and will check up cement that has a **flash set.** For the method of making these tests see Appendix C.

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* Table based on Hool & Johnson's "Concrete Engineer's Handbook," 1st Edition, Copyrighted 1918, by McGraw Hill Book Co., Inc.

Test cement for time of set and soundness.

See Jobs Nos. 20 and 21, Vol. II (in part).

17. Aggregates. The concrete is made up of aggregates bound together by the cement. These aggregates are chemically inert. The aggregates are divided into two classes:

(*a*)	**Fine**	(as sand).
(*b*)	**Coarse**	(as broken stone).

Either type is usually specified as being dense, hard, strong in compression, and insoluble in water.

Fine aggregates are understood to be those portions which will pass a ¼-inch mesh sieve. They include what is ordinarily known as **sand** (¼ inch to 0.5 mm. in diameter); **silt** (0.5 to 0.005 mm. in diameter); and **clay** (less than 0.005 mm. in diameter). They exist because of the disintegration of rock by **weathering.** They naturally, therefore, possess qualities like the rock from which they were formed and exist in **pockets, river beds,** or **beaches.** The period over which they were formed is usually many years in length, hence the variation in quality and the presence of foreign substances.

Coarse aggregates are arbitrarily taken to be those portions which remain upon a ¼-inch mesh sieve. The strength and durability of a concrete are closely linked to like qualities of this portion of the mix. Thus, any crushed rock of a **durable** character, or any **clean, hard, tough** gravel which will not readily disintegrate is considered usable. Among the rocks that are most used for this portion of concrete are **granite, trap,** or **hard limestone,** especially when the aggregate is to be a large size. It is the custom, where small size aggregates are to be used, to specify any sound or clean rock, which is known to be free from objectionable minerals.

Gravel. At some stage in the formation of fine aggregates the rock passes through the stage that ordinary gravel presents. Thus it seems that the use of gravel should be extensive in concrete construction, as **both** the **coarse** and **fine** aggregate are here **found together.** Again we are safe in saying that the quality of the gravel is dependent upon the parent rock. If the gravel has not been confined in small pockets so that it has had a chance to decompose, it may be considered as good an aggregate as crushed rock. The important thing to note again is the **cleanness** of the gravel, and too great stress cannot be laid upon this feature.

Information on gravel pits. **Bank-run gravel** is not suited to important work, unless by careful test the mixture of sand and pebbles is known to be **well graded** and free from impurities. The ordinary bank-run material will not be suitable because:

(1) The sizes are not well graded, so that a 1–6 mixture will not be equivalent to a 1–2–4. There is usually **twice** as much fine material as is desirable, and therefore **more cement** is needed. The bank gravel must usually be screened in the interest of economy and uniformity.

(2) The gravel may be **dirty** because the top soil, with loam and other vegetable matter, has not been stripped from the surface. There may be **clay pockets, shaly layers,** and **rotten stone.**

(3) The material of the pit is usually in **alternating** layers of fine and coarse material, and will **not** be **uniform** when delivered to the work.

The material should be **screened** into the various sizes needed for the different classes of jobs. For small work this may be done on the job.

Large commercial plants, with conveyors and power screens, are designed to develop deposits of gravel, producing

cobbles, ballast, concrete, sand, plaster sand, coarse aggregate, etc. The material is cleaned, sorted, and supplied as ordered.

At times, the "concrete" worker will, however, be under the necessity of using bank-run gravel. He should insist that the bank be stripped of top soil and the gravel be taken from that part of the pit that he knows to be right. He should **determine** just what **sizes** are **lacking** for a well-proportioned aggregate and see that these sizes are supplied. For instance, if there is not enough of the finer sand, he will see that it is supplied for the job, or if more coarse material is needed, this also can be added. By an intelligent handling of the pit, he can get reasonably good results without separating and recombining the material. He should have an inspector at the pit, unless the workers are intelligent and anxious to bring proper material to the job.

Prob. 17*a*. How many feet are there in 1 meter? How many millimeters in 1 meter? How many centimeters in 1 meter? 0.5 mm. (millimeter) is what fraction of an inch?

Solution. The meter is defined as the distance between two lines on a platinum-iridium bar kept at the International Bureau of Weights and Measures near Paris, the bar being at the temperature of melting ice. The legal definition of the yard in the United States is $\frac{3600}{3937}$ of a meter. Therefore a meter must be $\frac{3937}{3600}$ of 36 inches or 39.37 inches.

The meter is divided into tenths, hundredths, and thousandths, the first called the decimeter, the second the centimeter, and the third the millimeter. 1 mm. is therefore $\frac{39.37}{1000}$ inches, or 0.03937; 0.5 mm. then is 0.01968, or approximately 0.02 inch.

Prob. 17*b*. What decimal part of an inch would the mesh be that would just pass powdered clay?

Prob. 17*c*. What would be the dimension of a sieve mesh in inches that would just pass sand as defined?

18. How to Use Pit-Run Gravel. Since large amounts of pit-run gravel are used, it is worth while to know how much more cement to use, when the per cent of sand increases, in order to obtain a concrete of equal strength. Of course the gravel must be clean.

Mr. R. W. Crum of the Iowa Highway Commission reports rules in the Proceedings of the American Society for Testing Materials for 1919, p. 469, as shown in the following diagrams covering three classes of concrete:

Class I, suitable for reinforced concrete in general, watertight concrete, and base course of concrete pavement. It should range in strength from 2400 to 3000 pounds per square inch. The base values are 42 per cent sand and 1 : 4½ mix. (Fig. 21 (*a*).)

Class II, suitable for first-class foundations, gravity section piers and abutments for bridges, and base course of non-reinforced floors and walks. It should range in strength from 1800 to 2400 pounds per square inch. The base values are 42 per cent sand and 1 : 5½ mix. (Fig. 21 (*b*).)

Class III, suitable for large foundations and heavy mass work in general. It should range in strength from 1200 to 1800 pounds per square inch. The base values are 42 per cent sand and 1 : 7 mix. (Fig. 21 (*c*).)

Mr. Crum's recommendations are as follows:

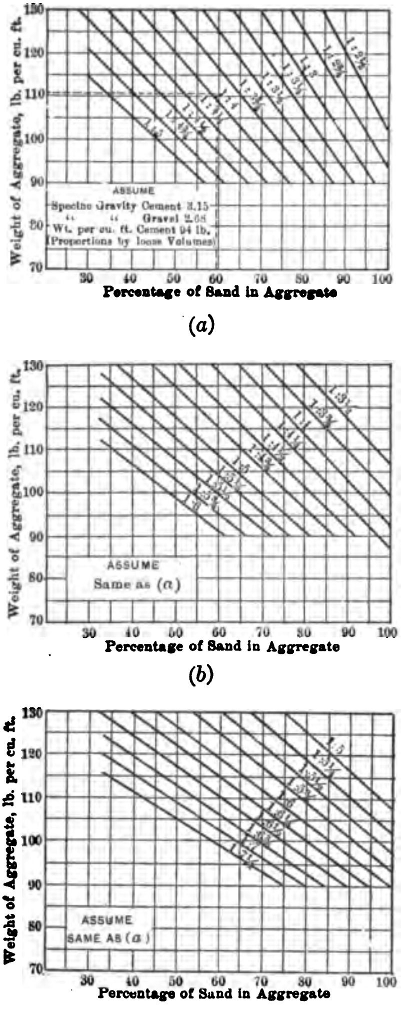
Weigh the mixed sand and gravel and determine the weight per cubic foot, loose. **Sieve** through the ¼-inch sieve and determine the percentage of sand. Then in the diagrams (Fig. 21):

Start on the horizontal line at the per cent of sand and run up vertically.

Start on the vertical axis and run out horizontally. Where the two lines meet is the proper mix as shown by the slant lines.

Example. The aggregate of sand and pebbles weighs 110 pounds per cubic foot. The per cent of sand is 60. The two lines meet at a 1 : 4 mix. (Fig. 21(*a*).)

Example. If the per cent of sand is 45 and the weight is 112 pounds per cubic foot, the mix is 1 : 4½.



(a)

(b)

(c)

FIG. 21. DIAGRAMS FOR USE IN PROPORTIONING PIT-RUN GRAVEL FOR CONCRETE.

By means of many experiments conducted for the purpose of determining the proper remixture of sand and gravel for various purposes the curves in this figure have been evolved. No doubt these are only practical approximations for the most economical mix. and in each structure of any size they should be checked.

The practice of the Iowa Highway Commission is as follows:

SPECIFICATIONS FOR PROPORTIONING PIT-RUN GRAVEL
IOWA HIGHWAY COMMISSION *

	Percentage of gravel passing a No. 4 sieve	Proportions cement to pit-run gravel	Quantities, bbls. cement for 1 cu. yd. plastic concrete
Class A for Bridges	55	1 sack to 4.0 cu. ft.	1.68
	up to 65	1 sack to 3.75 cu. ft.	1.80
	up to 75	1 sack to 3.50 cu. ft.	1.92
	up to 85	1 sack to 3.25 cu. ft.	2.00
Class B for Bridges	55	1 sack to 5.0 cu. ft.	1.37
	up to 65	1 sack to 4.5 cu. ft.	1.47
	up to 75	1 sack to 4.25 cu. ft.	1.57
	up to 85	1 sack to 4.0 cu. ft.	1.66
	up to 95	1 sack to 3.75 cu. ft.	1.79
Base Course, Monolithic, Brick and other Pavements	42	1 sack to 7.0 cu. ft.	1.00
	up to 55	1 sack to 5.5 cu. ft.	1.25
	up to 65	1 sack to 5.0 cu. ft.	1.35
	up to 75	1 sack to 4.5 cu. ft.	1.50
Curb and Gutter	42	1 sack to 4.5 cu. ft.	1.52
	up to 55	1 sack to 4.0 cu. ft.	1.68
	up to 65	1 sack to 3.75 cu. ft.	1.80
	up to 75	1 sack to 3.5 cu. ft.	1.92

Of course it is safer to separate the pebbles and sand, and then to recombine, and this should be done when the circumstances permit it.

(*Perform Job No. 31, Vol. II.*)

Prob. 18*a*. A concrete is to be mixed for a paving base for a roadway. The gravel weighs 105 pounds per cubic foot and the percentage of sand is 65. What mix would you use? (See Fig. 21.)

Prob. 18*b*. If the same gravel is to be used for heavy foundation concrete, what mix would you use? For the walk?

19. Extraneous Substances in Aggregates. Impurities occur in aggregates in the form of **clay, silt, organic matter, mica, iron sulphide,** and **dust.** These all act as **separating**

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* Mr. Crum in "Concrete," July 1919, p. 9.

agencies between the cement and the sand or stone. Clay and silt occurring in amounts up to **10 per cent**, or possibly as high as **15 per cent**, when evenly distributed through the mass, are not seriously harmful. If they are uneven in their distribution, however, they form separate masses which are detrimental to the density of the concrete. Organic materials not only prevent adhesion between the cement and aggregate, but it has often been found that very **small portions** of such impurities have **delayed the set** and **impaired the strength** of the cement. Mica, itself a scaly substance, readily decomposes upon exposure to the air, and will not combine physically with the mortar, lying in a free state in the mass. Iron sulphide in concrete mixtures combines with oxygen in the presence of water, forming sulphuric acid, which later attacks the concrete. The dust often found in crushed stone is crusher dust, and it is advisable to **screen** and **wash** this material from the crushed stone before using.

20. Proportioning. The cement and aggregates are mixed together in definite proportions with the object of forming **a dense, compact mass.** For the best concrete the sand should, roughly speaking, fill in the openings in the broken stone, and the cement should fill the remaining openings. Naturally, the best mixture will be of graded sizes of aggregates, so that the space left to be filled by the cement will be as small as possible. Instruction upon the principles of proportioning to attain this end will be given under **Void Determination,** Chapter IV and in Vol. II. Ordinarily the proportions are selected by the designer, such as 1 cement, 2 sand, 4 broken stone or gravel, by volume, meaning 1 cubic foot of cement, 2 cubic feet of sand, 4 cubic feet of broken stone, and written as **1–2–4.** One bag of Portland cement is one cubic foot packed. This 1–2–4 is a strong concrete. For less severe service, the proportions are **1–2½–5, 1–3–6.** The idea back of these proportions is that in sand or broken stone there is **one-half of the volume in voids.** Thus 1 part of cement will fill the voids in 2 parts of sand, and 2 parts of sand will fill the voids in 4 parts of stone. The weaker concretes have a **weaker mortar,** but still enough sand to fill the voids in the stone.

Of course, 4 cubic feet of stone, 2 cubic feet of sand, and 1 cubic foot of cement will **not make 7 cubic feet** of concrete, **but** only about **4⅔** cubic feet of concrete. Why is this?

This description of proportioning is rough and general, but will serve as a basis for further considerations, when we will attempt to find out the best proportions of sand and coarse aggregate to suit the gradation of sizes of the aggregate in order to make the densest concrete. See Appendix and Vol. II.

21. Quantity of Materials Needed for 1 Cubic Yard of Concrete. Mr. William B. Fuller evolved a simple rule for the calculation of quantities of concrete materials of average condition. This is worth knowing about, but as before stated, the best proportioning for any group of materials must be determined by test. Based upon the assumption that the barrel contains 3.8 cubic feet of material he proposes the following formulæ:

$$C = \frac{11}{c + s + g},$$

$$S = C \times s \times \frac{3.8}{27},$$

$$G = C \times g \times \frac{3.8}{27},$$

in which **c**, s, and g are the number of **parts of cement, sand,** and **stone** in the mix; C, the number of **barrels of packed cement;** and S and G, the number of **cubic yards of loose sand and stone,** respectively. The result will be the amount of material required for one cubic yard of concrete.*

(A barrel of cement is 4 bags.)

(Refer to Jobs Nos. 29, and 30 Vol. II.)

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* For well-graded aggregate these quantities are 5 per cent too high.

Example. Find the number of cubic feet of cement, sand, and stone required to make one cubic yard of 1–1½–3 concrete?

Solution.

$c = 1$
$s = 1\frac{1}{2}$
$g = 3$

$$\text{therefore } C = \frac{11}{1 + 1\frac{1}{2} + 3} = 2 \text{ barrels,}$$

$$\text{and} \qquad S = 2 \times 1\frac{1}{2} \times \frac{3.8}{27} = 0.42 \text{ cubic yard,}$$

$$\text{and} \qquad G = 2 \times 3 \times \frac{3.8}{27} = 0.84 \text{ cubic yard.}$$

As a barrel of cement is 3.8 cubic feet, and a cubic yard contains 27 cubic feet, we will need

7.6 bags, cubic feet of cement (8 bags),
11.34 cubic feet of sand, and
22.68 cubic feet of stone.

For usual proportions these values become **Materials Required for One Cubic Yard of Concrete.**

TABLE III

Proportions	Cement, Bbls.	Sand, cubic yards	Broken stone or gravel, cubic yards
1–1–2	2.75	0.39	0.78
1–1½–3	2.00	0.42	0.84
1–2–4	1.57	0.44	0.88
1–2½–5	1.29	0.45	0.90
1–3–6	1.10	0.46	0.92

Prob. 21*a*. Check the values in Table III by Fuller's Rule.

Prob. 21*b*. How many barrels of cement, cubic yards of stone and sand will be required for a 1–2–5 concrete? A 1–3–7 concrete?

22. Hand Mixing of Concrete. Almost immediately after the batch of concrete is mixed, the hardening action begins. The amount in the batch should never be more than can be **placed in half an hour,** and the number of batches should be so regulated that they will be completely used up when the work is stopped, either at the noon hour or at the end of the day.

With these limitations in mind, a batch, based upon the number of bags of cement to be used in it, is started by **measuring out** the required amount of **sand** upon the mixing platform. This is **spread evenly** over the platform and the proper amount of **cement is added.**

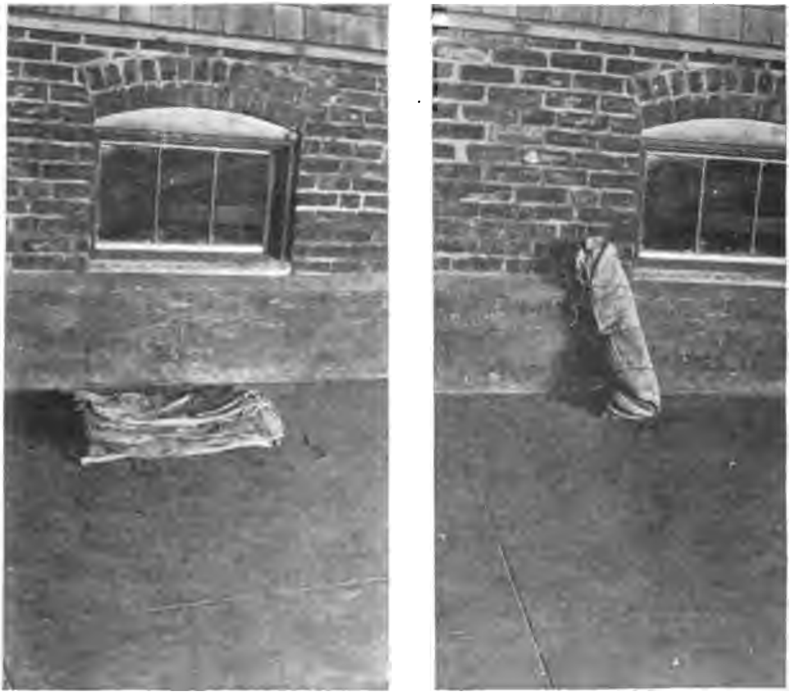
Cement may be had in bags of cloth or paper, or in bulk (cars or barrels). The returned bags, if tied in bundles of fifty and if dry and whole, are worth about 15 or 25 cents each, delivered at the factory. It is, therefore, worth while to care for them properly each day. In this way they also serve as a **check on the amount** of cement used, and if the mix is kept uniform, it gives an accurate **record** of the amount **of concrete** placed. The paper bags are not returnable, but do away with the care of the cloth bags. On larger constructions, or where the work is being done in a damp place, the use of cement in barrels or in bulk is quite common. If the job is adjacent to a railroad siding, and proper plant facilities are provided, the use of bulk cement shipped in water-tight cars is advisable. The barrel of cement weighs 376 pounds net, while the bag weighs 94 pounds net, making just four bags to the barrel.

The customary method of **bundling cement sacks** is to count them out in lots of **fifty** and to place them upon the floor with two cross strings below and one longitudinal string above. The bundle is tied in the shape shown at (*b*), Fig. 22, and then the longitudinal string is tied. The bundle is **tagged** for shipment.

To spread the cement upon the sand, it is customary to take the bags by the **ears** and move them from side to side, releasing the cement as they pass backwards. (Fig. 23.)

This method spreads the cement more **evenly without** excessive **dusting.** Just before the bag is entirely empty it is shaken to remove all the cement lodged within the bag and is pulled up with a quick jerk.

The cement is then spread over the fine aggregate, and the men turn the mix through two or three times, until the mass is of a uniform color. Flat shovels are used for this work, and two men are placed at each end of the platform **facing each other.** Each man works his shovel **close** to the platform, moving it **diagonally** toward the shovel of his partner. Lifting each shovel and turning it over with a **circular motion** at the same time, tends to make a more uniform and rapid



(*a*) (*b*)

FIG. 22. BUNDLING CEMENT BAGS.

Quite a saving can be effected by careful attention to the empty bags. This also serves as a check on the amount of concreting done for the day. If bags are tied up in bundles of fifty and properly tagged they may be sent back and credited to the contractor at about nine cents each. They should be dry and without tears or rips.

mix. Fig. 24 shows these positions, which can be acquired by practice only.

The stone, or coarse aggregate, **previously wet,** is then measured and spread upon the cement and sand mixture, and the batch is again turned through two or three times. The whole mass is then **troughed,** and the proper amount of

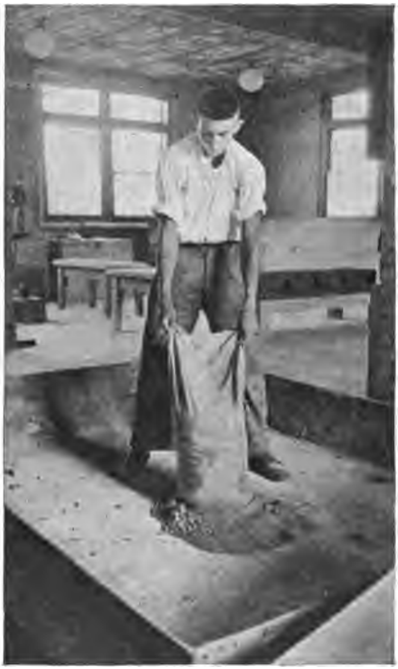


FIG. 23. METHOD OF EMPTYING A BAG OF CEMENT.

In most concrete work full bags of cement are used. If for a hand mix, the bag should be turned up-side-down and moved back and forth and with a movement backward so as to let a small portion out all along the top of the mix. Before the bag is completely empty it should be shaken thoroughly to remove all the cement, and this method will also do away with the great amount of cement dust that is occasioned by careless handling.

water added. This amount is carefully determined in the first batch, and the following batches are gauged similarly by **measuring the water** by pailfuls for each mix.

The dry material is then turned into the water, care being exercised that no water is allowed to get away, as it will carry with it a portion of the cement. When this mixing operation has been repeated until the entire batch appears **free of flowing water,** the men turn it over again several times until all the stones are covered with the mortar, and the mass appears to be of a **uniform consistency.**

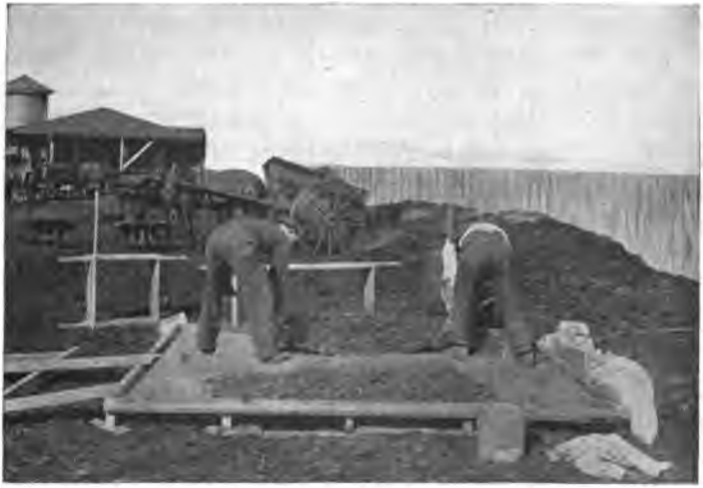


FIG. 24. POSITION OF MEN AND SHOVELS FOR MIXING.

The work of mixing the concrete by hand can be made very ineffective by improper handling of the shovels. The two shovels should be brought toward each other diagonally and should be lifted at the same time. In throwing the material over, the shovels should be given a circular overturning motion with the object of spreading the material over as great a surface as possible. *Courtesy Portland Cement Association.*

On small jobs, where one man mixes, and one man places the concrete, it is better to use a box with vertical sides and sloping ends. The materials are **mixed** dry **with a hoe,** and left in a pile near the end of the box. Water is added as small portions of the mass are mixed and drawn to the end of the box. With one man mixing, the hoe is more effective than the shovel.

(Perform Job No. 32, Vol. II.)

The **amount of water** to use has been, and still is, an unsettled matter. It is detrimental in too large quantities. The concrete used in footing slabs such as we have under consideration is usually termed **dry concrete.** This means that it should have as little water as will allow it to perform the duty of **fluxing** the cement over the many surfaces of the sand grains and stone particles. In addition it should be **free from oils, acids, alkalies, and vegetable materials.** Insufficient water makes the placing of the irregular particles difficult, and there should be enough water to lubricate these substances so that they will flow easily into all parts of the forms. **Excess water leads to washing** the grains of aggregate, excess of entrained air causes porosity, and, should there be a possibility of an escape of concrete, the water will flow off with much of the cement. If entirely confined, **excess water,** upon evaporation or other form of subsequent removal, **may form a pocket.**

23. Placing of Concrete. The placing of concrete for footing slabs can be greatly simplified by moving the mixing board adjacent to the slab and **shoveling** the mix **directly** into the excavation. When this method is used, the platform is allowed to project over the excavation slightly, and a **dash-board** is placed upon the opposite bank to prevent the concrete from carrying the soil into the footing with it. Fig. 25 shows a section of the trench and mixing board with the dash-board in place. If it is impossible to shovel directly from the platform to the footing, the concrete is shoveled into concrete wheelbarrows (Fig. 49), and these are carted on planking to the proper place and discharged. In this case care must be exercised and proper precautions taken to prevent the carrying of soil into the footing as before.

(Perform Job No. 63, Vol. II.)

Dry concrete should be deposited in layers no thicker than **6 inches** and should be thoroughly **tamped** with a wood or steel tamp (Fig. 26), until the mortar comes to the top of the mix. For wall footings the work should be carried on so that in case the work must be stopped, a **stop-board** can be introduced. This should be placed vertically as shown in Fig. 27. In Fig. 28, the position taken by the workman in using the tamp is illustrated.

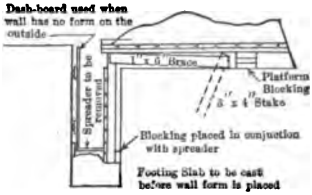

Dash-board used when wall has no form on the outside
Spreader to be removed
1" x 6" Brace
Platform Blocking
3" x 4" Stake
Blocking placed in conjuction with spreader
Footing Slab to be cast before wall form is placed

FIG. 25. SKETCH OF SECTION OF TRENCH SHOWING METHOD OF CONCRETE PLACING.

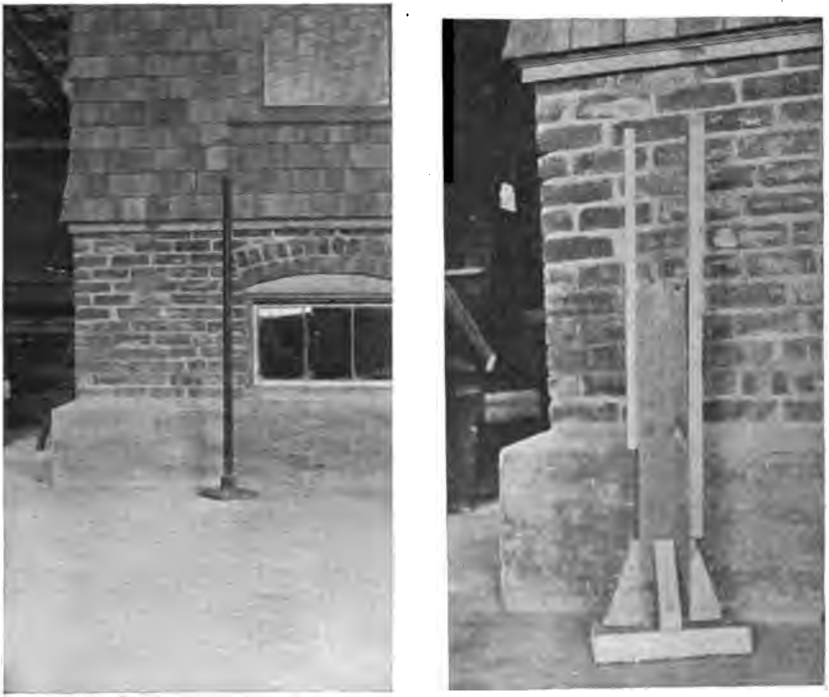
As mentioned in connection with Fig. 18, the placing of concrete direct, without the use of barrows or carts, is here illustrated. The difficulty in this method is that soil is apt to be carried down into the trench with the concrete unless a dash-board is used. Even where the wall is formed on both sides it is advisable to have a dash-board so as to avoid the loss of any of the concrete.

24. Problems for Review.

Prob. 24*a*. How many cubic feet and cubic yards of concrete in the west foundation wall and footing? What is the mix of the concrete (see Specifications)? How many barrels of cement and cubic yards of sand and stone will be required for this work? (Place in estimate form — Problem 11*a*.)

Prob. 24*b*. Calculate the yardage of 1–3–6 concrete in the foundation walls of the building. How much cement, sand, and stone will be required? (See Art 21.)

Prob. 24c. Calculate the yardage of 1-2-4 concrete in the column footings; in the retaining walls; in the first floor reinforced slab over the boiler and coal rooms; in the curb, gutter, and steps.



(a) (b)

FIG. 26. CONCRETE TAMPS.

The concrete used for pavings is usually comparatively dry and as such must be well tamped to bring all the parts into action. This can be accomplished with either the steel or wood tamp. The former, (a), is a stock tool and the latter, (b), can be made upon the job from plank and timber.

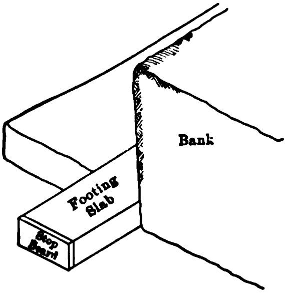


FIG. 27. STOP BOARD FOR FOOTING SLAB.

The casting of concrete on most jobs must be stopped off at the end of the day's work. The proper method of stopping for footing slabs is to place a stop board vertically so that if a plane of cleavage is developed later it will allow the footing to bear evenly foot by foot rather than bring the pressure upon a thin wedge of concrete which is not as thick as the entire footing.

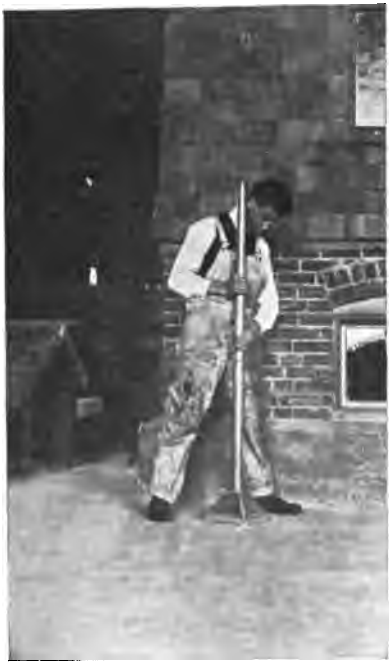


FIG. 28. POSITION TAKEN IN TAMPING.

In tamping dry concrete the tool should be lifted vertically between the legs of the workman, who straddles the work as shown.

CHAPTER IV

COLUMN FOOTINGS

25. Types. The column footings for this small building are one of the four kinds of reinforced concrete footings ordinarily used. For a discussion of their **design** the student is referred to other authorities. The four, merely as a matter of interest here, are:

(*a*) **Single.**
(*b*) **Combined.**
(*c*) **Cantilever.**
(*d*) **Raft foundation.**

The footings for the columns in this building are of the first kind. They are termed **spread footings,** the distribution of load from the superstructure being accomplished by extending the **mat** beneath the column sufficiently to carry a safe allowable unit pressure on to the soil of 2250 pounds.

The spreading of footings may be accomplished by

(*a*) **Stepped footing.**
(*b*) **Grillage footing.**
(*c*) **Reinforced concrete footing.**

Fig. 29 shows these types, (*a*) being the stepped footing with **offsets** so arranged as to form the angle of 60° indicated; (*b*) the **steel grillage** footing for the same spread, and encased in concrete; and (*c*) the typical reinforced concrete footing for a like load.

Each of these requires forms for the offsets or batters, and these are constructed as simple **boxes,** layer for layer, the horizontal surfaces being left as they would turn out after tamping. Fig. 30 shows the form boxes for the stepped footing, (*a*), and for the reinforced concrete footing, (*b*); for the grillage footing the box would be of a different size and shape, but it would be of similar construction.

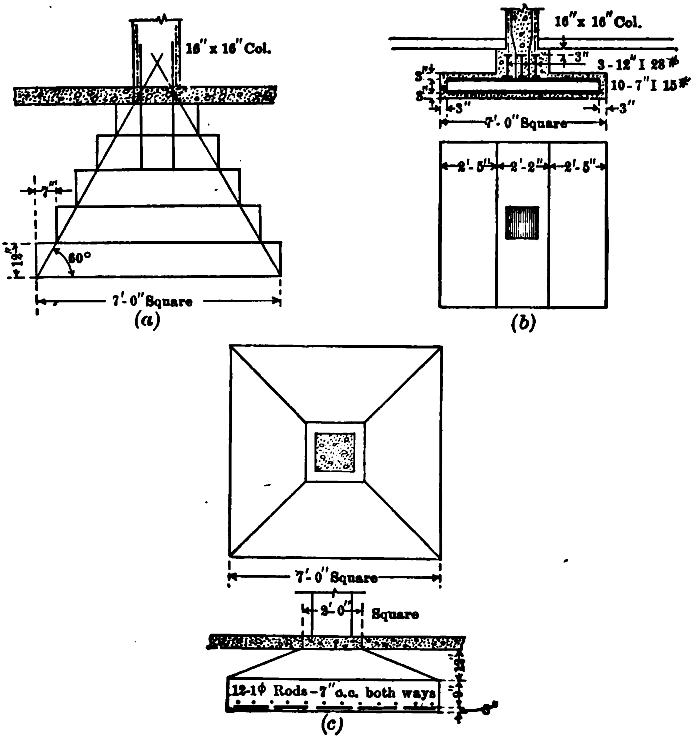
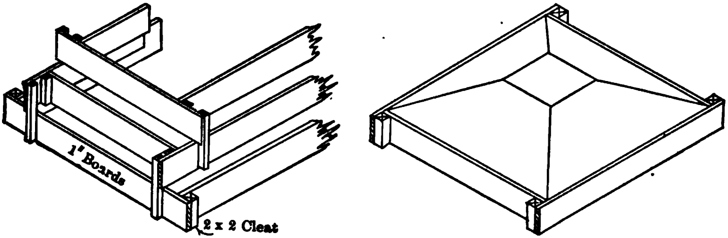


FIG. 29. TYPES OF SPREAD FOOTINGS.

Footings such as these carry the load from the columns or walls directly to the soil, as distinguished from pile or caisson foundations which are used for heavy loads upon soils where the bearing power is low. In the stepped footing, (*a*), the spread is accomplished by the use of concrete or masonry of some kind without any reinforcement. The other two types of spread footings utilize steel either in structural shapes or in the form of concrete reinforcement. The structural steel variety are known as grillage footings, (*b*), and the concrete in these acts as a protection for the steel only. The reinforced concrete type, (*c*), allows the concrete to carry its share of the stresses in compression and shear, while the reinforcement takes the tension.

Each of the column footings in our building is reinforced in some way, as shown in the details (Plate I). Where reinforced concrete is used, the correct proportioning of the aggregates and the water is important, as the strength of the footing involves **more than** ordinary **compression.** The plates in each case are made of tamped concrete slightly **more wet** than the concrete used for plain footings.



(*a*) (*b*)

Fig. 30. Form Boxes for Footings.

The forming of footing slabs may be accomplished as shown here or the slab may be formed by driving sheeting. In the design of these forms the location of cleats must be such that the form will not bulge. While this bulging increases the strength, there will be an excess of concrete. The panels, as the sides are called, are often made of planking instead of boards. The cleats can usually be 2 × 2 lumber. After one of the layers is cast the form for the succeeding layer is set, and so on.

Prob. 25*a*. How many cubic yards of concrete in the footing shown in Fig. 29(*a*); 29(*b*); 29(*c*)?

Partial Solution. Area of lowest slab is 7 × 7 feet = 49 square feet. Depth of this slab is 12 inches. Therefore, its volume is 49 × 1 cubic foot = 49 cubic feet. The area of the second slab is $[7'\text{-}0''-(2 \times 7'')]^2 = [7'\text{-}0''-1'\text{-}2']^2 = [5'\text{-}10'']^2 = [5.83']^2 = 5.83 \times 5.83 = 34$ cubic feet for 5″ slabs.

[Consult Palmer's "Geometry" for volume of truncated pyramid to solve 29(*c*).]

Prob. 25*b*. Which of these three footings has the largest amount of concrete? How much excavation would be required for each? Which requires the most excavation?

Prob. 25c. If the footings shown in Fig. 29(*a*) and (*b*) are of 1–3–6 concrete and that in (*c*) of 1–2–4 concrete, calculate the barrels of cement and cubic yards of sand and stone required for each.

Prob. 25d. How many pounds of structural steel are needed to build the grillage footing? How many pounds of reinforcing steel are required to build the footing shown in Fig. 29(*c*)? (See Table IX.)

Prob. 25e. If the excavation costs $3.50 per yard, structural steel 6 cents per pound in place, reinforcing steel 4½ cents per pound in place, cement $2.37 per barrel net, and sand and stone $2.50 per yard, what is the cost exclusive of forms and placing of concrete in each case? Which is the cheapest? What percentage would you rate each one at if the grillage footing was considered 100 per cent?

Prob. 25f. Estimate the number of board feet of form required for the footings shown in Fig. 29 by reference to Fig. 30. If forms cost 15 cents per square foot of surface formed, what is the cost of the forms for each type?

Prob. 25g. In connection with your answers for Problems 25*e* and 25*f*, how much does each footing cost, if concrete can be mixed and placed for $4.50 per yard?

26. Proportions of Concrete Materials. Since the concrete for the footings and the frame needs to be of better quality, attention should now be given to more exact methods of proportioning.

Probably no phase of concrete construction has been operated in as careless and thoughtless a manner as that relating to **proportions of material.** Contractors, in general have, with the sanction of engineers, adopted arbitrary proportions which they have applied regardless of the variation in the aggregate. As great as may be the number of grades of aggregate, so great, too, are the number of proportions in which they should be combined.

In general, we may say that the ideal which the properly proportioned concrete should approach is that constitution which a natural rock presents. An examination of the fractured surface of a concrete mixture will reveal the fact that its structure is that of a number of larger particles bound into a mass by the mortar composed of cement and sand. If we examine this **matrix** under a high-powered microscope, we find that it, too, is made up of larger grains, bound or set up in a matrix of cement. The ideal condition is to have these grains as close together as possible, allowing the cement, which is the weakest constituent of the mass, **to occupy** as **little space** as is consistent with a proper **coating** of the grains.

The water, without which concrete cannot be formed, is not allowed a place in our assumptions. It undoubtedly occupies space, and if in excess, will leave a somewhat **porous** concrete after it has evaporated. Thus there is an amount of water, dependent upon the amount of cement, which will just accomplish the result desired, and the use of more water than this is detrimental. It is necessary, however, to use more water to accomplish **economical deposition** of the concrete at times. These items place limitation upon the strength and permeability of the concrete which we cannot overcome.

Superimposed upon arbitrary proportions, **inaccurate measurement** of materials has tended toward even worse conditions. No consistent consideration has been paid to the **condition** of the aggregates; the constituents have not been measured and as a result what was called 1–2–4 concrete has upon investigation been found to vary from 1–1–2 to 1–5–9 on a single job. Arbitrary proportions cannot be ignored however. On work of the ordinary type it is sometimes more economical in time and labor to accept as near a correct result as possible. The ordinary proportions which may be so designated are:

(*a*) **1–1–2;**
(*b*) **1–1½–3;**
(*c*) **1–2–4;**
(*d*) **1–2½–5;**
(*e*) **1–3–6.**

(Perform Job No. 36, Vol. II.)

Prob. 26a. Is concrete very much different from natural stone as a structural material? Your reasons?

27. Proportioning Concrete to Suit the Materials. While the usual procedure is to work to arbitrary proportions as fixed in the specifications, the concrete foreman should have a knowledge of the principles governing the **fixing of the proportions** to suit the character of the aggregates that are available. On large jobs large sums of money will be saved by a **scientific study and control** of sizes of the aggregate, and the separation and remixing of the various sizes of particles to form a **dense** concrete. In this way the amount of cement needed is cut down and the concrete is of a better quality. For this purpose the aggregate must be properly **graded** in various sizes.

(Perform Job No. 33, Vol. II.)

28. Sieve Analysis. The idea underlying the process is that the **various sizes** of sand and stones are **found out** by a sieve analysis, and then the **various sizes are mixed together** in certain proportions to form a well-graded aggregate. If the sand as supplied has too much fine material the sifting and further recombining will correct the deficiency.

A weighed sample of sand or stone, selected from three or four parts of the pile, is passed through a set of sieves of standard size, and the amount retained in each sieve is noted. These values are then plotted on **co-ordinate** paper, using the sieve openings as **abscissæ,** or horizontal divisions, and the percentage retained upon the sieves as **ordinates** or vertical divisions. Fig. 31 illustrates the plotted curve of a medium sand and a standard stone such as one would meet in actual practice.

(Perform Jobs Nos. 25, 26 and 27, Vol. II.)

Prob. 28a. What percentage of particles ¾ inch in diameter passed the sieve as illustrated by the curve in Fig. 31?

Solution. Pass along the horizontal axis (axis of abscissæ) until you reach the 0.75 vertical line. Move up to the curve and then horizontally to the left to the vertical axis (axis of ordinates) and read 56 per cent.

Prob. 28*b*. What percentage of medium sand passed the No. 10 sieve?

Prob. 28*c*. What is the size of the particle comprising 40 per cent of the crusher run stone?

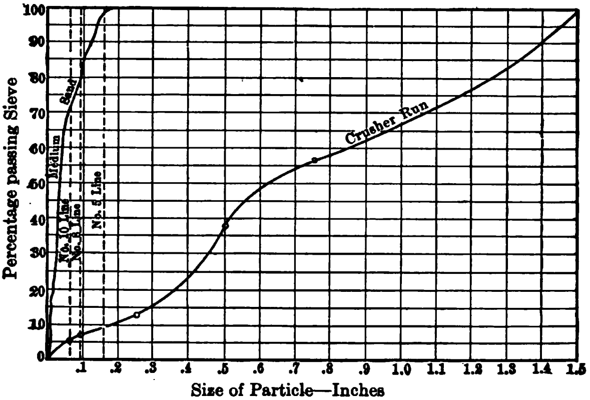


FIG. 31. SAND AND STONE GRADING CURVES.

The application of co-ordinate curves to the presentation of data is of great value. It gives one a visual expression of the conditions, and allows one to draw conclusions more accurately. It also shows any discrepancies which may have crept into the work because of errors of one kind and another. This method of plotting results of sieve analyses has been generally followed.

29. Information on Sieves. Sieves are listed by numbers which agree approximately with the **number of meshes per lineal inch.** The standard dimensions of the frame are:— 8 inches in diameter and 2¼ inches high. The sieve should be tested to see if the openings are the proper size. Below ¼-inch openings the sieves are of woven brass wire. The ¼-inch and larger are preferably made of brass plates with holes punched to proper size.

Material passing through the ¼-inch sieve is classed as sand, and above ¼ inch as coarse aggregate. This is an **arbitrary division.** If the entire material with the division size at ⅛ inch will furnish good concrete, as shown by actual test, this arbitrary sizing may be changed. However, the ¼ inch has been almost universally adopted and should be held to in the interest of uniformity, unless some **large interest** suffers.

TABLE IV

SIZE OF SIEVES

Tyler Series		A. S. T. M. Standards *	
No. or Size	Size of square opening, inches	No. or Size	Diameter of opening, inches
200 mesh	0.0029	100	0.0055
100 mesh	0.0058	80	0.0067
48 mesh	0.0116	50	0.0114
28 mesh	0.0230	40	0.0142
14 mesh	0.0460	30	0.0197
8 mesh	0.093	20	0.0335
4 mesh	0.185	10	0.079
⅜ inch	0.370		
¾ inch	0.740		
1½ inch	1.500		

The student will appreciate that the sieve size is about the size of the particles and thus gives a **basis for the gradation** of these in the sand. The sieves used are a commercial article and are made of brass. The proper sizes can be **nested** with a pan and cover, in order, from the coarsest to the finest used in the test. These are then shaken either by hand or mechanically. Fig. 32 shows the standard sieves and a nest of sieves in a mechanical sieving machine known as the **Rotap.** The screens in the sieves are made of woven brass wire with commercial numbers approximating the number of meshes per inch. Some of the sizes manufactured and frequently used are given in Table V. **Two sets** of standard

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* 1918 Book of A. S. T. M. Stds.

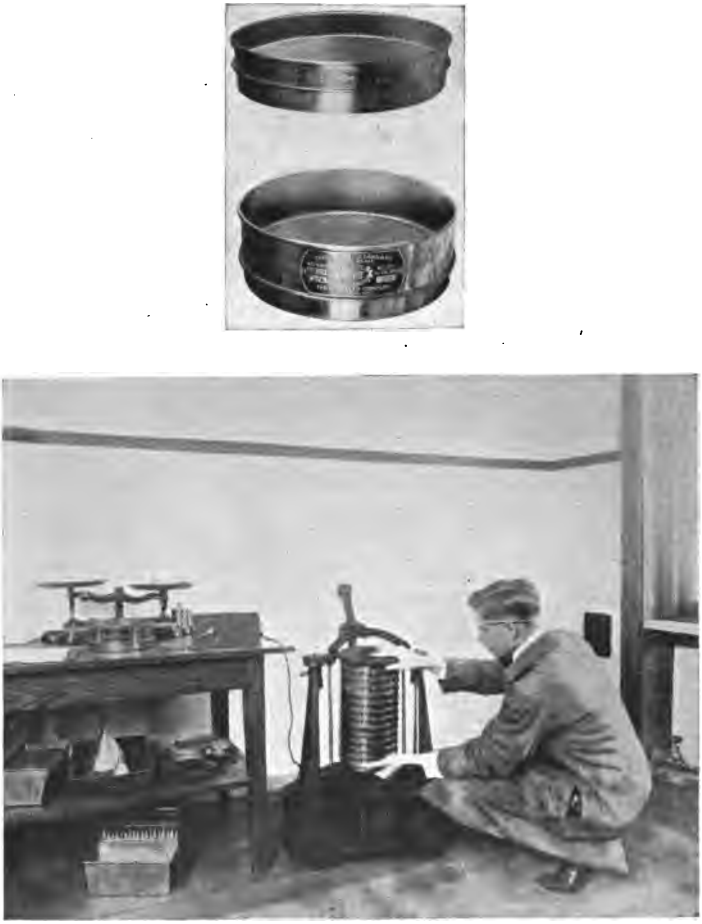

FIG. 32. STANDARD SIEVES AND NEST OF SIEVES IN ROTAP SIEVE SHAKER.

The old method of hand sieving is gradually being replaced by the more constant and accurate machine sieving. Such tests are merely comparative and if one destroys this comparison by inaccurate, inconstant hand methods the results are not of much use. The importance of sieve analyses however is witnessed by the fact that such a machine has been worth while patenting. *Courtesy W. S. Tyler Co.*

nests have been used. One of these has Nos. **5–10–20–40–80–100** nested together.

Another set, recently adopted by the New York Public Service Commission, contains Nos. **4–8–16–30–50–100.**

Table V

SIEVES COMMONLY USED IN AGGREGATE ANALYSIS

Commercial No.	5	8	10	16	20	30	40	60	100	200
Approximate size of hole in inches	0.165	0.096	0.073	0.042	0.034	0.020	0.015	0.009	0.0055	0.0026

For the analysis of coarse aggregate the customary sieves have openings **2, 1½, 1, ¾, ½ and ¼** inches in diameter.

(*Perform Jobs No. 28 and 31, Vol. II.*)

Table VI

The following specifications as adopted by the **Public Service Commission of New York City** are a good guide to acceptable aggregate. When mechanically graded they should show the following sieve percentages:

Fine aggregate. Size of opening	Commercial sieve No.	Maximum per cent passing	Minimum per cent passing
0.200	4	100	95
0.100	8	95	85
0.042	16	75	40
0.021	30	50	20
0.011	50	30	2
0.006	100	6	0

Not over **6 per cent** of **silt** by dry weight should pass a 100 sieve when screened dry. Not over **10 per cent** should pass a 100 sieve when washed on the sieve in running water. The field test by **decantation** should not exceed **10 per cent** by volume.

Coarse aggregate. Size of hole	Maximum per cent passing	Minimum per cent passing
2	...	100
1½	100	95
1	80	40
¾	60	25
½	40	10
¼	5	...

(*Perform Job No. 39, Vol. II.*)

Prob. 29*a*. Lay out a plot such as shown in Fig. 31 with 0.002 inch for ⅛-inch horizontally, and with the same vertical scale, and locate the lines for the sieves given in Table VI.

Prob. 29*b*. Plot a curve for the acceptable aggregate as given in the specification of the Public Service Commission of New York City.

30. Void Determination. One process formerly used in examining sand and other aggregates is to **determine the voids.** An aggregate with small voids requires less cement.

(*Perform Jobs No. 23 and 24, Vol. II.*)

One method is to fill a box with the sample of sand and find out **how much water** may be poured in. But the water in the sample and the air retained in the sample make this measurement very uncertain.

The **best method** is to weigh a cubic foot of the sample of sand and compare its weight with the weight of a cubic foot of solid stone. The difference is accounted for by the air spaces. The method depends upon the fact that the solid weight of the sand particles or of the stone pieces is the same as the solid weight of the rock from which it originally came.

The following table will enable the per cent of the voids to be known when the weight of the sample has been determined.

The **per cent of moisture** in the sample is determined by drying it out and then determining its weight.

The importance of a well-graded sand aggregate will be evident from the following facts about voids:

The voids or open spaces in aggregates that are to be filled by the cement or mortar **should be as small** as possible. They are expressed as percentages of the volume of the aggregate. They do not **depend** upon the size of the aggregate so much as **upon** the **gradation of sizes.**

The voids in fine sand with all particles of the same size

TABLE VII *

PERCENTAGES OF VOIDS IN SAND AND GRAVEL CORRESPONDING TO DIFFERENT WEIGHTS PER CUBIC FOOT

(Average Specific Gravity of 2.65)

Per cent moisture by weight	Weight per cubic foot										
	75	80	85	90	95	100	105	110	115	120	125
0	54.7	51.7	48.7	45.7	42.7	39.6	36.6	33.6	30.6	27.5	24.5
1	55.2	52.2	49.2	46.2	43.2	40.2	37.3	34.2	31.2	28.2	25.3
2	55.6	52.7	49.8	46.7	43.8	40.8	37.9	34.8	31.9	28.9	26.0
3	56.1	53.1	50.3	47.3	44.4	41.4	38.5	35.5	32.6	29.7	26.7
4	56.5	53.6	50.8	47.8	45.0	42.0	38.1	36.2	33.3	30.4	27.5
5	57.0	54.1	51.3	48.4	45.5	42.6	39.8	36.9	34.0	31.2	28.3
6	57.5	54.6	51.8	48.9	46.0	43.2	40.4	37.5	34.7	31.7	29.0
7	57.9	55.1	52.3	49.5	46.6	43.8	41.0	38.2	35.4	32.6	29.8
8	58.3	55.5	52.8	50.0	47.2	44.5	41.6	38.9	36.1	33.3	30.6
9	58.8	56.0	53.3	50.6	47.8	45.0	42.3	39.5	36.8	34.0	31.3
10	59.2	56.5	53.9	51.1	48.4	45.6	42.9	40.2	37.5	34.7	32.1

are practically the same as voids in coarse sand with all particles of the same size. For minimum voids, therefore, the **sizes should vary.**

The voids in a mass of shot are about **26 per cent,** when they are placed to touch one another in the smallest space. But if poured at random in a vessel, the voids will be found to be not less than **44 per cent.** Sand contains about **50 per cent** voids, if of uniform size. By proper mixing of sizes the voids may be **reduced to 34 per cent;** less cement will be needed, therefore.

But, while the coarse sand and fine sand of uniform size have the same per cent of voids, the **coarse sand is better,** because the water forces the fine sand apart and increases the voids. Up to about 8 per cent water poured into fine sand will increase the volume of the sand. However, still more water compacts the sand and reduces the volume. Therefore the voids in fine sand may be from **33 to 44 per cent** depending upon the amount of moisture in the sample.

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* Hool & Johnson's "Concrete Engineer's Handbook," p. 26.

The effect of this contained water in a sample of sand makes ordinary methods of measuring voids in the sample very uncertain.

Round particles like gravel will **contain less voids** than angular particles.

Voids in dry sand range from **25 per cent** for a **coarse, well-graded natural sand** to **40 to 44 per cent** for a **very uniform or screened sand.** The range for **coarse aggregates** is **25 to 55 per cent.**

Since the measurement of voids is so inexact, and since the relation of the cement, sand, and broken stone or gravel is different when mixed together from that which the void measurements would indicate, proportioning by calculations from void measurements is not advised.

What is advised?

Prob. 30*a*. Using a scale of 10 pounds to the inch horizontally and 1 inch = 10 per cent voids vertically, plot curves for percentages of moisture of 2, 4, 6, 8, and 10 (Table VII). What conclusions do you draw from these curves?

31. Proportioning by Scientific Principles. Considerable attention is now being given to a **scientific study of proportioning,** but engineers are not agreed upon the most valid method. In Appendix A the student will find the method advised by Taylor and Thompson. See also Vol. II for a discussion of the method by surface area and fineness modulus.

(*Perform Jobs No. 40 to 46, Vol. II.*)

32. Importance of Consistency and Good Mixing. The importance of using **as little water as possible,** and of thorough mixing, is as great as that of refined methods of proportioning. The student should read pp. 75 to 78 on this matter.

33. Concrete of Maximum Density. It is commonly conceded that the **densest concrete is the best** and the proportions of cement and aggregate to make the densest concrete must be determined. The study of aggregate by sieve analy sis, or by voids, is not always possible or advisable in the field, and various field tests have been instituted to do this work.

The simplest of these is the best, and one of them commonly used employs a pair of scales and a rigid cylinder such as a piece of pipe about 10 inches in diameter. The cement, water, and stone are mixed to the specified proportions, each of the materials being weighed separately. The mix is then tamped into the pipe and its height measured. This process is repeated, varying the proportions of sand and stone. The water used in each case should be sufficient to produce the same consistency for each batch. Each time the **height of the concrete** in the cylinder is noted, and by successive trials in this manner the densest concrete (that which occupies the least space, which works well, and which has enough mortar to cover the stones) is determined.

Ordinarily the proportions are selected in advance, and specifications are drawn up on the aggregates. It then becomes the duty of the inspector to **examine the aggregate** and the **resulting concrete** and to correct any departures from the standard. The items to bear in mind in this work are:

(1) Good and coarse aggregate and cement. **Test them.**

(2) Materials supplied in exact quantities. **Test for measures.**

(3) Concrete mixed at least one minute with the minimum of water that will produce a concrete that is workable under the conditions of the job. Use batch machine.

(4) **Watch** the concrete and correct for variations as explained.

(*Perform Jobs No. 34 and 35, Vol. II.*)

34. Consistency of Concrete. The term, **consistency,** refers to the condition of the green concrete as shown by its **flowing quality** which is controlled by the **amount of water** used in the mixing. The amount of water, as previously brought to the attention of the student, has much to do with the action of the cement, the density of the resulting concrete, and the appearance of the work when complete.

The concrete must be **workable** in the particular job. If a small chimney is being built with a trowel and board, the concrete must be dry. If a large building is being erected by chuting the concrete, it must flow. Again, a sidewalk base must be dry enough to be tamped.

Water serves **three important purposes** in concrete, namely:

(1) **It combines with the cement** to form a binding material. If not enough water is used, the chemical action will be incomplete; if too much is used, the binder will be too dilute. The proper amount depends upon many factors. More is required for a waterproof concrete than for the strongest concrete. The strongest concrete results from a medium **quaking consistency,** with 5½ to 6 gallons of water per bag of cement. A drier concrete will attain early strength, but will not continue to gain as rapidly. A better concrete will be about right when it quakes like liver under tamping, and also of about the consistency of thick cream, when the concrete will flow down a slope without the coarse aggregate separating out. Excess water forces the cement particles apart until their action is destroyed.

(2) **Water** also **acts as a carrier** of the cement. If there is too much water, the solution is weak, and will not attach itself to the irregularities of the aggregate. Too much water allows air bubbles to be carried by the concrete. The **excess water** also **occupies space in the concrete,** and when it dries out open spaces or pores will be left, thus weakening the concrete. These pores also allow the action of frost.

(3) **Water lubricates the concrete** and allows it to flow into position. **Too much is** generally **used** for this purpose. The proper flowing can be brought about by a cleaner and more thorough mixing.

(Perform Job No. 38, Vol. II.)

The more we learn about concrete, the more certain it is that **too much water is injurious** to concrete. The only safe rule is to use just enough water to produce a plastic or live concrete that is workable on the particular job and to mix it for a long enough time. The exact amount of water cannot be stated, because,

(1) The materials may be wet.
(2) Fine materials require more water.
(3) Coarse materials require less water.
(4) Rich mixtures require a relatively less amount of water to produce a workable concrete.

It is, therefore, important for the concrete worker to learn the **proper appearance** of good concrete, which is of such a consistency that it is workable on the job, and to watch the mixing operation with a view to time and the correction of materials and water. **Good concrete never has isolated batches of stone or mortar,** and is always **uniform in texture and color.** In general, merely as a point at which to start, it may be said that **six gallons** of water used **for each bag** of cement and **mixed** at least one minute, or better **a minute and one-half,** will produce good concrete. This mixture will generally be the quaking mixture called for.

The following information is a guide to consistency, which should best be learned from experience:

For buildings and structures with **wide members,** a material that will flow slowly into place is advised. In the wheelbarrow it will show a level surface but the large aggregate will not sink below the surface. There should not be any excess of water. From 6½ to 7 gallons of water per bag of cement is recommended, reduced for wet aggregate.

For reinforced tanks, and structures that must be **waterproof** and with narrow sections, a more fluid concrete, with a finer aggregate, and with an easy flowing consistency is advised. The coarse aggregate must not separate from the mortar. The amount of water to produce such a mixture is 7½ to 8 gallons of water per bag of cement.

For tamped concrete from 6 to 6½ gallons of water per bag of cement is advised.

For **columns**, piles, and so forth, a concrete drier than the above, to avoid the formation of **laitance**, and wet enough to give a good surface and to flow around the bars, is mostly used.

For the base of sidewalks and **pavings** where a finish must be applied, a dry concrete, with about **6 gallons** of water, per bag is used. Water will appear upon its surface after tamping. In all cases, make trials first.

Tests show the following effect upon the strength of concrete of various percentages of water, based on weight of aggregates.

Table VIII

EFFECT OF WATER UPON THE STRENGTH OF CONCRETE

Consistency	Per cent of water	Compressive strength, lbs. per sq. in.
Very dry...........	5.4	2500
Dry, well rammed..	5.4	4200
Medium............	6.9	5200
Wet................	9.2	4800
Very wet...........	11.0	3500

Prob. 34*a*. Select your scale of abscissæ and ordinates, and plot the information given in Table VIII in the form of a curve. (Omit "Very Dry Consistency.")

35. Abram's Measure of Consistency. **Professor Duff A. Abrams** of the **Structural Materials Laboratory, Lewis Institute,** has devised, as a measure of consistency, the **sag** or shortening of a concrete cylinder. For details, see Job No. 35, Vol. II. The test is performed as follows:

(See Bulletin No. 1, Structural Materials Laboratory, Lewis Institute, April, 1919.)

Mix the concrete thoroughly, adding the estimated amount of water.

Tamp the concrete into a galvanized-iron mould which is a cylinder 6 inches in diameter and 12 inches high. The cylinder is filled in two layers. Each layer is tamped for forty strokes with a $\frac{5}{8}$-inch round steel rod **18 inches** long.

Then draw the mould up off the specimen and note how much the specimen **shortens or sags** in height.

A relative consistency of 1.00 (**normal consistency**) requires the use of such a quantity of mixing water as will cause a **slump of $\frac{1}{2}$ to 1 inch** in a freshly moulded 6 by 12-inch cylinder of about 1 : 4 mix upon withdrawing the form by a steady, upward pull. This consistency is somewhat dry for most concrete work, but can be used where light tamping is practicable.

A relative consistency of 1.10 (10 per cent more water than required for normal consistency) represents about the **driest concrete** which can be satisfactorily used in concrete road construction. Under the conditions mentioned above, this consistency will give a **slump of about 5 to 6 inches.**

A relative consistency of 1.25 represents about the **wettest consistency** which should be used in **reinforced-concrete building construction.** Under the conditions mentioned above, this consistency will give a **slump of about 8 to 10 inches.**

$$\textbf{The water-cement ratio} = \frac{\textbf{Volume of water}}{\textbf{Packed volume of cement}}.$$

For a 1 : $4\frac{1}{2}$ mix this ratio is 0.88, and will yield a consistency of 1.0; that is, 0.88 cubic feet or 6.6 gallons of water to 1 sack of cement. See Vol. II for other tests.

Use as little water as possible, just enough to give a workable concrete for the job in hand after prolonged mixing. The amount required will depend upon the proportions, the gradation of sizes, and the amount of moisture in the aggregate.

Prob. 35*a*. Using relative consistencies as abscissæ, and the slump as ordinates, plot a curve for "Measure of Consistency" from the information in Job No. 3, Vol. II.

36. Steel Placing in Footing Slabs. Sections 3 and 4, Plates I and VI, show reinforcement in the column footings (1) to (6). These details indicate the steel as being 3 inches up from the bed of the footing slab. The concrete for these footings should be a little more wet than that used for the plain footings under the walls described in Chapter III. This is necessary in order that the **concrete mortar may flow all around the steel.** This precaution insures the proper **bonding** of the steel and the concrete, besides the proper **protection** of the steel.

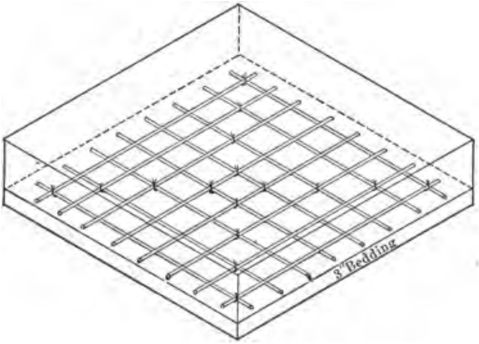


FIG. 33. MATTED STEEL FOR FOOTING.

The danger of misplacement or movement of the reinforcement after it is placed must be overcome by wiring the various rods together. This can be done by preparing a mat of the steel beforehand and placing it at the proper level in the footing.

Where steel is placed in such constructions as this, or when the concrete surface is to be bedded in or against damp soil or in water, the minimum distance from the steel to the exterior of the concrete should be **3 inches.** The concrete should also be well **tamped around the steel** at the time it is placed, for adequate protection. When the first three inches of this construction are in place, the steel for the tension reinforcement is laid upon the tamped bed. Sometimes the required number of bars or rods are placed on the concrete loosely. This is not good practice, as the deposition of the remaining concrete may disarrange the bars sufficiently to impair the strength of the footing. The better way is to **mat the steel as** shown in Fig. 33, being careful to **wire** the rods of one layer to those of the layer at right angles with it.

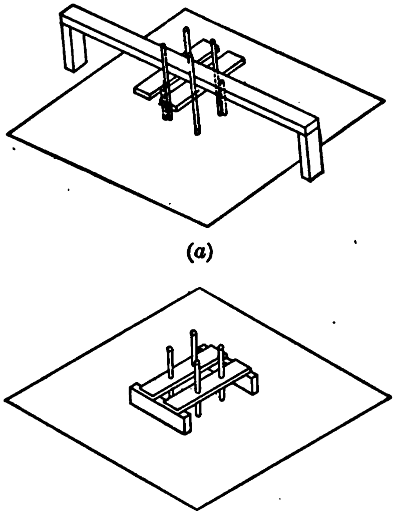


FIG. 34. TEMPLATE PLACING FOR DOWELS.

Where a piece of concrete work is a part of a monolithic structure it is necessary to connect the steel in the unit cast to the steel in the unit which is to be cast later. This may be accomplished with dowels as shown, but rods are often extended from the unit cast, of such length that they will bond with the steel above. To set these dowels in position a template or wood spacing piece is provided.

The details call for four **dowels** for each footing. These are placed in the footing to furnish a bond between it and the concrete of the column. There are usually **as many dowels** in the footing **as** there are **rods** in the column and they should be of the **same size.** The lap required is usually specified as **forty diameters,** this being the length of rod which will develop its tensile strength by bond with the concrete. In this case the student will see that it is impossible to obtain such embedment, and the bars are hooked at their ends to make up the required bond. In placing these dowels, it is best to provide a **template** for their proper location, by fastening two template strips to a stay-piece which is then fastened to stakes driven on either side of the footing. Each of the templates is then drilled for the proper location of the dowels, and the rigging is placed over the steel. Fig. 34(*a*) shows this method of dowel placing and another, (*b*), frequently used which employs the template only, depending upon the friction between the wood and the concrete for stability. This work is very often done in a hit-or-miss fashion, and the dowels are later bent to meet the conditions. This careless practice impairs the effective strength of the dowels. The dowels are usually placed to come within the column steel, as shown in Fig. 35, in plan and elevation. Note the **convention** used for indicating rods above and rods to be placed.

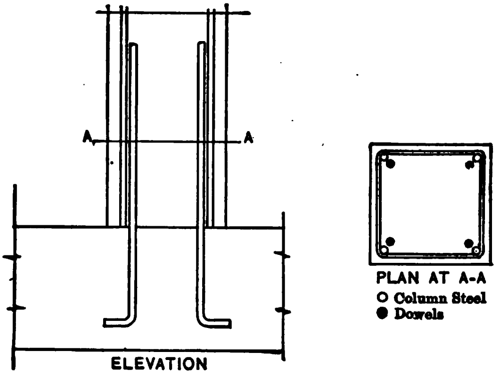


Fig 35. Relation of Dowels to Column Steel.
Refer to Fig. 34.

(Perform Jobs No. 61 and 62, Vol. II.)

37. Types of Reinforcement. The reinforcement used in concrete construction may be either **round** or **square** in section, and either **plain** or **deformed.** The bond developed between the plain steel and the concrete is of **an adhesive nature**, but the deformed bars give additional strength by the development of **mechanical** bond.

Many types of deformed bars are on the market, among which are the **American,** manufactured by the American System of Reinforcing; **Corrugated,** manufactured by the Corrugated Bar Company; **Havermeyer,** manufactured by the Concrete Steel Company; **Rib,** made by the Truscon Steel Company; and the **Inland,** made by the Inland Steel Company.

(Perform Jobs No. 47, 49 and 50, Vol. II.)

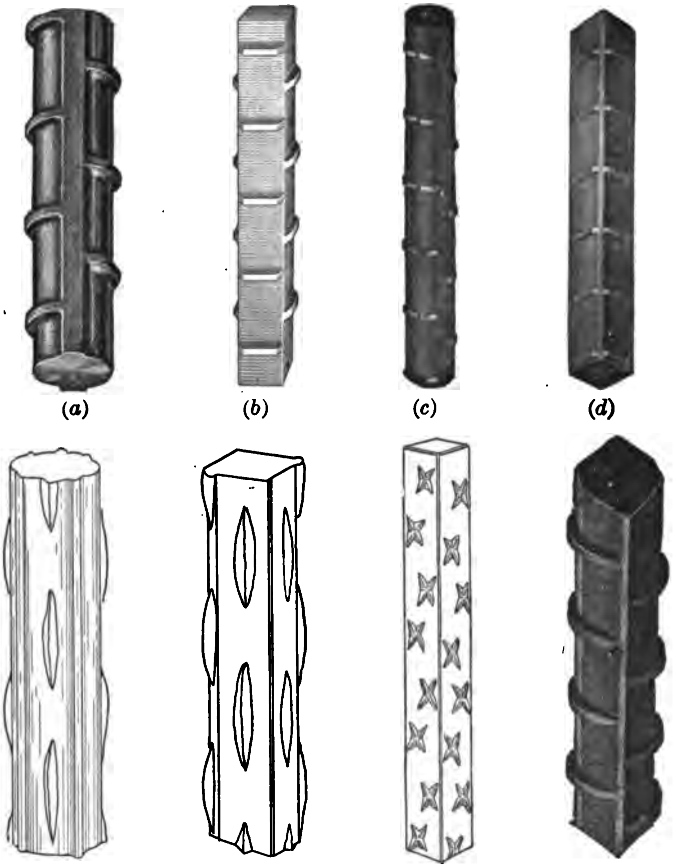
Sometimes the engineer gives only the **area of steel** required for each part of the construction. In this case it is necessary for the contractor to place the necessary number of bars of the correct size, to give this area. Some of the deformed bars are heavier than others on account of the lugs, and so the weight per foot of length vary with the type. In order that the student may have a record of these variations and a handy reference for the cross-sectional area of the various sizes and kinds, Table IX is given below:

TABLE IX

PICTURES, AREAS, AND WEIGHTS OF BARS AND RODS

Name	Illustration	Manufacturer	Item	Size						
				3/8	1/2	5/8	3/4	7/8	1	1 1/8
Corrugated Rounds	(*a*)	Corrugated Bar Company	Area	0.11	0.20	0.31	0.44	0.60	0.78	0.99
			Wt./ft.	0.38	0.66	1.05	1.52	2.06	2.69	3.41
Corrugated Squares	(*b*)	Corrugated Bar Company	Area	0.14	0.25	0.39	0.56	0.76	1.00	1.26
			Wt./ft.	0.49	0.86	1.35	1.94	2.64	3.43	4.34
American Rounds	(*c*)	American System of Reinforcing	Area	0.11	0.20	0.31	0.44	0.60	0.79	0.99
			Wt./ft.	0.38	0.68	1.05	1.51	2.05	2.68	3.38
American Squares	(*d*)	American System of Reinforcing	Area	0.14	0.25	0.39	0.56	0.77	1.00	1.27
			Wt./ft.	0.48	0.85	1.33	1.92	2.61	3.40	4.31
Havermeyer Rounds	(*e*)	Concrete Steel Company	Area	0.11	0.20	0.31	0.44	0.60	0.79	0.99
			Wt./ft.	0.38	0.67	1.04	1.50	2.04	2.67	3.38
Havermeyer Squares	(*f*)	Concrete Steel Company	Area	0.14	0.25	0.39	0.56	0.77	1.00	1.27
			Wt./ft.	0.48	0.85	1.33	1.91	2.60	3.40	4.30
Inland Squares	(*g*)	Inland Steel Company	Area	0.14	0.25	0.39	0.56	0.77	1.00	1.27
			Wt./ft.	0.49	0.86	1.34	1.93	2.63	3.43	4.35
Rib Bar Squares	(*h*)	Truscon Steel Company	Area	0.14	0.25	0.39	0.56	0.77	1.00	1.27
			Wt./ft.	0.48	0.86	1.35	1.95	2.65	3.46	4.38

One of the problems in the selection of steel sizes is to **keep the number of** different **sizes** and lengths as **low** as possible. The rolling of **even eighths** of an inch in size is more frequent than that of the sixteenth-inch sizes. The stock of the latter is therefore usually very low, and to get shipments of them from the mill is a slow process. It is



(*a*) (*b*) (*c*) (*d*)

(*e*) (*f*) (*g*) (*h*)

Illustrations for Table IX.

good general practice to proportion the steel so that the sizes vary between the limits of $\frac{1}{4}$ **inch to** $1\frac{1}{4}$ **inches.** The steel companies have tables of extras, as they call them, on steel, dependent upon **size, length,** and **total tonnage.** Table X gives a summary of these extras.

TABLE X

EXTRAS ON REINFORCEMENT

Size.	
$\frac{3}{4}$ and larger	Base
$\frac{5}{8}$ to $\frac{11}{16}$	\$0.05
$\frac{1}{2}$ to $\frac{9}{16}$	.10
$\frac{7}{16}$	.20
$\frac{3}{8}$	.25
$\frac{5}{16}$	.35
$\frac{1}{4}$	.50
Length.	
Over 48 inches and less than 60 inches	\$0.05
24 inches to 48 inches inclusive	.10
12 inches to 23 inches inclusive	.20
Under 12 inches (on application) ...... not less than	.30
Tonnage.	
Over 1,000 pounds but less than 2,000 pounds	\$0.15
Less than 1,000 pounds	.35

Naturally, then, **steel selection** becomes a **problem in economy** for the contractor. Engineers very often do not follow the rules of economy laid down above. They use steel in sixteenth-inch sizes, and if the contractor can get the sanction of the engineer for a change to the eighth-inch sizes, it may be possible for him to save some money and surely some time in delivery. This, however, necessitates the drafting of a new steel schedule and the making of new steel placing plans. To do this correctly requires only a careful study of stock at hand and a mastery of some of the jobs which it is planned to carry on in connection with this text.

Prob. 37*a*. Plate VI, Beam 6, calls for 2-$\frac{7}{8}''\varnothing$ rods bent, and 1-$\frac{7}{8}''\varnothing$ rod straight. What number and size of square bars would you use in place of the round?

Solution.

$$\begin{aligned} 2\text{-}\tfrac{7}{8}''\varnothing \ \text{Area} &= 2 \times 0.60 = 1.20 \\ 1\text{-}\tfrac{7}{8}''\varnothing \ \text{Area} &= 1 \times 0.60 = \underline{0.60} \\ & 1.80 \end{aligned}$$

Substituting

$$\begin{aligned} 2\text{-}\tfrac{3}{4}'' \ \square \ \text{Bars} &= 1.12 \\ 1\text{-}\tfrac{7}{8}'' \ \square \ \text{Bar} &= \underline{0.76} \\ & 1.88 \end{aligned}$$

Prob. 37*b*. If $\frac{7}{8}''\varnothing$ rods were not available and you had $\frac{5}{8}''\varnothing$ and $\frac{3}{4}''\varnothing$, how many of each would you use to give the same cross-sectional area? Would these go into an 8-inch beam? How would you arrange them? Sketch. Would the size of the aggregate affect the spacing of the rods?

Prob. 37*c*. Substitute square bars for the steel given for Beam 5.

Prob. 37*d*. Arranging your steel in a double layer with 2 inches between layers and bars 2 inches on centers (o.c.), substitute rods of $1''\varnothing$ or under for the $1\frac{1}{8}''\varnothing$ rods given for Beam 1, keeping the same percentage of bent steel.

38. Problems for Review.

Prob. 38*a*. What structural sections are ordinarily used in buildings?

Prob. 38*b*. How are angles designated? Tees? I-beams and channels?

Prob. 38*c*. What is the weight per foot of:

$4 \times 3 \times \frac{3}{8}$ ∟?
$6 \times 4 \times \frac{1}{2}$ ∟?
$3 \times 3 \times \frac{1}{4}$ ∟?

Prob. 38*d*. If the footings in Fig. 29 were all cast of 1–2–4 concrete, what would be their relative costs in place?

Prob. 38*e*. Make a sieve analysis of a bank gravel and plot your results. If you recombined the sand and coarse aggregate to get a 1–6 mix, how much sand or gravel would remain unused?

Prob. 38*f*. If the steps in the footing shown in Fig. 29(*a*), were 18 inches high, what yardage of concrete would be required? Is this larger or smaller than as shown? What conclusion do you draw?

Prob. 38*g*. If you had ⅝″Ø rods, 4-inch o.c. specified for a footing slab, how many rods would there be per foot of width? What cross-sectional area would this give?

Prob. 38*h*. If you had to use ½″□ bars instead of ⅝″Ø rods, how many inches on center would they be?

Prob. 38*i*. Plot a curve for ⅝″Ø rods, using the sectional areas per foot as ordinates and the spacing of the rods as abscissæ.

Prob. 38*j*. If a cross-sectional area of 0.81 square inch is needed for a footing slab reinforcement, what spacing would you use from the curve of Problem 38*k*. Check arithmetically.

Prob. 38*k*. If the stiffness of steel beams is measured by their section modulus given under the Column "S," Axis 1–1 in "Carnegie," how many 8 **I** 18 beams would you use in place of the lower layer as shown in Fig. 29? How many 10 **I** 25?

CHAPTER V

CONCRETE WALLS

39. Wall Forms. Concrete sub-grade walls may require either **one-walled** or **two-walled** forms, depending upon the nature of the soil and the excavation. It is always better to form both sides of the wall wherever possible as the soil is very apt to absorb the water from the concrete and leave the wall porous and of a poor grade.

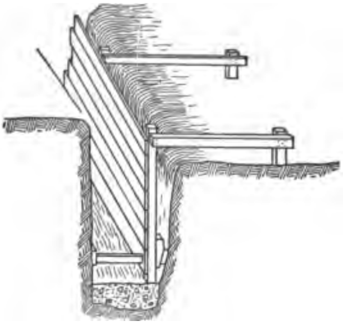


FIG. 36. CONSTRUCTION OF ONE-WALL FORM.

Where the nature of the soil will permit, quite a saving in forms can be effected by using the bank for one of the forming faces. The boarding for forms of this type is usually 1 inch or 1¼ inches thick and some even width. The head of the concrete and the spacing of the cleats which are usually 2 × 4 or 3 × 4 will indicate the thickness of lumber to use for the panels. The braces can be of 1 × 6 stock fastened to 2 × 4 stakes about 4 feet back of the excavation. This last dimension is determined by the nature of the soil.

Where the work calls for a form on one side of the wall, the form must be braced and plumbed independently. The customary construction of such a form is shown in Fig. 36.

Where an excavated basement exposes the form down to its base, the bracing could be applied as shown in Fig. 37. In either case, the form is built up before placing, so that one unit will lap on to the next. The spreader is then raised into

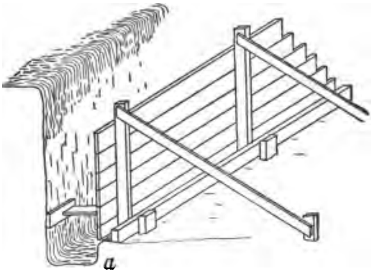


FIG. 37. CONSTRUCTION OF ONE-WALL FORM EXPOSED ITS FULL HEIGHT.

The sizes of lumber for such a form as this would be essentially the same as for that in Fig. 36. The stick running parallel to the form and adjacent to it is called a liner and should be a 2 × 4 or 3 × 4. This is staked into place by 2 × 4 sticks as shown.

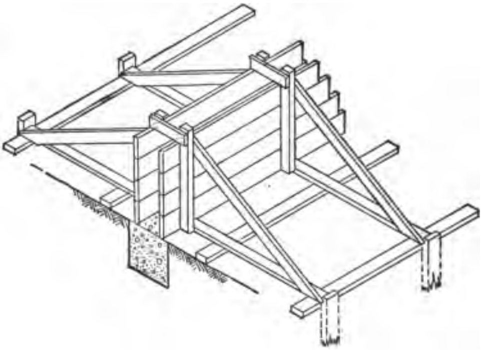


FIG. 38. CONSTRUCTION OF TWO-WALL FORM EXPOSED ITS FULL HEIGHT.

This is a common occurrence where buildings are built entirely above grade or for use in connection with interior concrete partition walls. The sizes of lumber to use here are similar to the ones used in like positions in Fig. 36.

place and the base **wedge** is driven as shown in Fig. 36, or the **scantling** (**a**) is placed as in Fig. 37. The wall is then plumbed and the braces are nailed in place to secure the form in that position.

(*Perform Job No. 47.*)

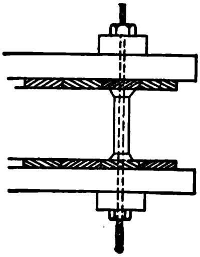


FIG. 39. PIPE SLEEVE TIE AND SPREADER.

It is noted that for the construction of wall forms two important items must be provided: spreaders and ties. The former act as truing pieces before the concrete is cast and in the placing of the form, and the latter hold the form to the proper size after the concrete begins to exert its pressure, tending to throw the wall out of shape or size. The use of a piece of pipe with a wedge piece at either end for the spreader and a bolt which passes through this pipe as the tie is quite common. When the form is stripped the bolt can be removed with the wedges and the holes plugged up with mortar leaving a finished unmarred surface. In this way the bolts are saved for future use.

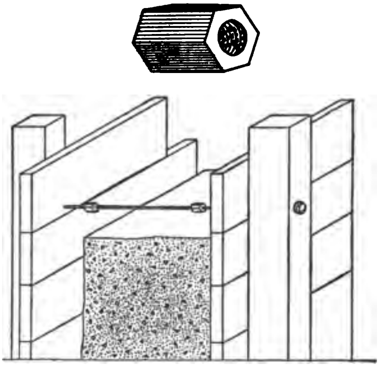


FIG. 40. MARION BAR COUPLING.

This coupling is used frequently to accomplish the tying of a wall. The outside bolts can be removed with a wrench and the holes left by this removal patched up. The rod and couplings remain inside the wall.

The two-wall form has been constructed in many ways, depending upon the height of the wall and the type of excavation. Where the wall is **low and exposed** on both sides, a form such as that shown in Fig. 38 is commonly used. It would be correct to use a duplicate construction, as in Fig. 37, in such a case.

High walls require considerable care in bracing and in tying the two walls firmly together. For this purpose, **bolts** or **wires**

are used. Many schemes have been developed for withdrawing bolts after the concrete has been placed. The earliest of these made use of a **pipe sleeve** cut about two inches shorter than the width of the wall, through which the bolts were passed. **Wood washers** were inserted over the ends of the sleeve. This allowed the sleeve to act as a spreader, while the bolt pulled the forms closely together. This type of tie

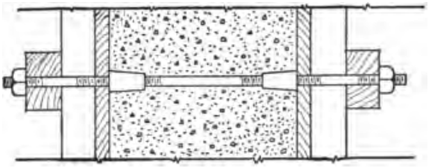


FIG. 41. UNIVERSAL FORM CLAMP.

An adaptation of the pipe tie and spreader is shown here. The cone nuts act as the spreaders, while the bolts passing through the form lumber are removable. The cones can be removed and reused as can the exterior bolts and nuts. The interior rod can be had in several lengths for varying thicknesses of walls.

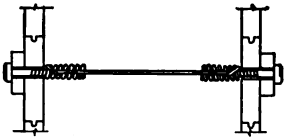


FIG. 42. THE TYSCRU.

This method of spreading and tying forms utilizes the lag screw. The wire at the end of the tyscru is twisted into a threadlike casing which will take the threads of the lag screw.

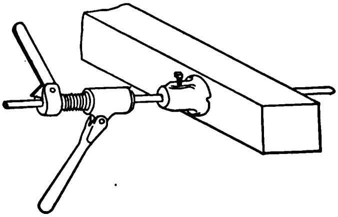


FIG. 43. THE UNIVERSAL CLAMP AND TIGHTENER.

This method of tying forms involves the use of a flanged coupling with a set screw, a ratchet clamp, and a threaded tightener. The clamp and tightener are brought up snugly to the flanged coupling, and the clamp is set. The tightener is then turned up toward the coupling until the form is well up to the spreaders. The apparatus can be used in the reverse fashion for entirely removing the rod after the forms are stripped.

is illustrated in Fig. 39. When the forms are removed, the bolts are usable the second time, and the wood washers are taken out of the concrete and the hole pointed up. Other methods suggest themselves readily, among the most common of which is the use of a short union in place of the wood washers and the withdrawal of rods after the concrete has set sufficiently to stand up by itself. To do this, a patented

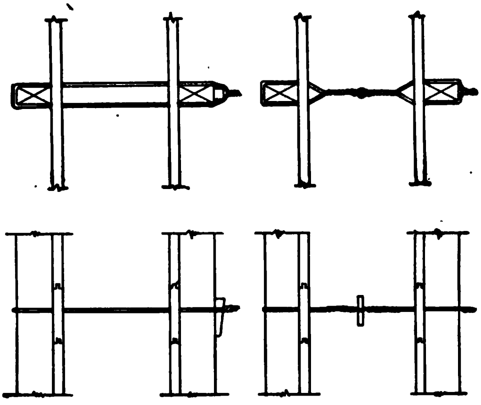


FIG. 44. SIMPLE TIES OF WIRE.

At times it is advisable to do away with the use of the methods of tying that involve patented articles, and then wire either twisted inside the form, as at (*b*), or wedged taut by wood wedges, as at (*a*), is employed. The objections to this method are that the wire will stretch somewhat and destroy the alignment of the forms.

rod or wire puller is used. Fig. 40 illustrates the **bar coupling** manufactured by the Marion Malleable Iron Works, Marion, Ind. In place of these, some contractors use the product of the Universal Form Clamp Company, Chicago, Ill., illustrated in Fig. 41, the "Tyscru" manufactured by the Unit-Wall Construction Company, New York City (Fig. 42), or the patented clamp and tightener made by the Universal Form Clamp Company. (Fig. 43.)

The use of **wire** instead of rods is advisable in some cases. This has prompted the development of schemes which the student should investigate as the occasion arises. The two simple schemes, unpatented, and very useful, are illustrated in Fig. 44.

40. Erection of Wall Forms. Probably not enough stress can be laid upon the two outstanding requirements of good form work:

(*a*) **Tightness.**
(*b*) **Rigidity.**

Without the former, **leaks** occur, and these are detrimental to the concrete in that they allow the cement and fine aggregate to run out, leaving porous spots which are not durable, strong, or waterproof. If the forms are not rigid and give way when the concrete is green, the work will have to be done over again.

The making and erection of forms and their making is one of the large items of expense in concrete building. The possibility of **using them again** tends to reduce this item. Forms which are constructed to facilitate removal without great loss of lumber or defacement can be used over **three** or **four** times. If the parts are so designed that **whole board widths** can be used without splitting, this will also result in economy of material and labor. It is not always possible to do this, but the good designer takes it into consideration.

The lumber used for forms will vary with the locality. It may be safely said that any wood which is **free from** large **knots** and **shakes,** and which has a **fair strength,** can be used. In New England the most common of these woods is **spruce. White pine** has been used, but it is more expensive, and is extremely soft, and does not stand up well when it has been used very many times. The use of **Norway** and **southern pine** is common too, and they both give good satisfaction. When the lumber comes to the job, it is very often not thoroughly seasoned. This is advantageous for forms, as the seasoned lumber would have to be laid with openings to allow for the swelling which takes place during the placing of the concrete. **Green lumber,** however, **is bad,** as it is apt to open up if the form is in place any great length of time before the concreting takes place.

(Perform Job No. 53, Vol. II.)

It is considered good practice to **keep** the **forms wet** until the concrete is placed, in order to avoid such difficulties.

The boarding for wall forms is usually **sheathing,** which is tongued and grooved and dressed on one face. This insures tight joints and a smooth surface, and is advised. The spacing of **cleats** will vary with the height of the wall and the thickness of the boarding. In general, Table XI can be used for small wall forms such as are found in this building.

TABLE XI

VERTICAL CLEATS FOR WALL FORMS

Head of concrete	Cleat Spacing	
	1-inch boards	1½-inch boards
Feet	Inches	Inches
2	26	31
4	20	26
6	16	21
8	14	18
10	13	16

(Perform Job No. 54, Vol. II.)

Prob. 40*a*. How many board feet in a 2 × 12 plank, 12 feet long?

Solution. A board foot is one foot of a 1 × 12 board. The cross-sectional area of this board would be 12 square inches. The cross-sectional area of a 2 × 12 plank would be 24 square inches. Therefore, each foot of a 2 × 12 plank would contain 2 board feet. Twelve feet would contain 12 × 2 board feet = 24 board feet.

Prob. 40*b*. Fill in the following table, indicating the board feet:

Length in feet	1 × 4	1 × 6	2 × 3	3 × 4	2 × 8	1¼ × 12
10						
12	4					
14						
16						20
18						

Prob. 40c. If the west foundation wall of the Lawlor Building were formed as shown in Fig. 37, how many board feet of lumber would be required?

ESTIMATE SHEET

Description	1 Number	2 Length	3 Size	4 Board feet	Calculations
Form faces . . .	7	45⅓	1 × 8	212	(1) 4′ − 4″ = 52″ 52 ÷ 8 = 7 − (2) 48′ − 0″ − (2 × 16″) 2′ − 8″ 45′ − 4″ = 45′ − 4″
Cleats	28	4⅓	3 × 4	122	(1) 45′ − 4″ ÷ 20″ = 27 1 end cleat extra = 28
Stakes	56	2	2 × 3	56	(1) 2 stakes per cleat, one near and one at end of brace, = 56
Braces	28	6	1 × 6	84	
Liners	1	45⅓	3 × 4	46	
Spreaders	10	2⅓	1 × 6	12	(1) 1 spreader for every 3rd cleat. $\frac{28}{3}$ = 10− (2) 16″ spreader 12″ shore 28″ = 2′ − 4″ long
Total	. . . . . .	. . . . . .	. . . . . .	. . 532	

Solution. From Table XI, 1-inch boards necessitate 3 × 4 cleats every 20 inches, as the head of concrete on this wall is 4 feet 4 inches. Assuming that the stakes could be driven, safely, at a distance of 4 feet from the form panel, the length of the 1 × 6 braces would be $\sqrt{4.33^2 + 4^2} = 6$. The stakes would need to be about 2 feet long and would be of 2 × 3 scantling. The spreaders and shores would be of 1 × 6, spaced at every third cleat.

Prob. 40*d*. Work up an estimate sheet for the forms required for the interior wall on the west side of the boiler and coal rooms, if the form is built as shown in Fig. 47.

Prob. 40*e*. Fig. 44 illustrates two methods of wiring a two-wall form. How many inches of wire would be required to run one line for a 16-inch wall, over 3 × 4 cleats, on 1¼-inch boarding? Try this, and compare results.

Prob. 40*f*. If the wall in Problem 39*d* was wired as shown in Fig. 44(*a*), at every second cleat, and twice in the height of the wall, how many feet of No. 12 gauge wire would be required? How many pounds would this be? (Consult Birmingham Wire Gauge.)

Prob. 40*g*. If a ¾-inch pipe spreader and ½-inch bolt were used in place of the wire, how much will this type of tying cost, if the pipe is worth 12 cents per foot (cut) and the bolts 6 cents per foot (threaded with nuts)?

(Perform Jobs No. 55, 56, 58 and 59, Vol. II.)

41. Simple Steel Details. The retaining walls in this building are **reinforced.** The student will note from Section 2, Plate I, that the reinforcing rods are both **bent** and **straight.** The bent rods are placed in the wall for the purpose of **tension** reinforcement.* The vertical part of the rod ties the wall to the footing slab and protects the wall against rupture. The horizontal part of the rod protects the lip of the footing slab from rupture. The wall with the possible bending, exaggerated, is shown in Fig. 45.

The detail of this rod is very simple but should be included in a well prepared set of details. The form the detail sheet would take is shown in Table XII. Note that the **straight** rods are not given a **mark,** but that the rods with a **bend** in them **are marked.** The number of lineal feet must be known as well as the size of the rod. The **number of bends**

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* (For further explanation see Chapter VI.)

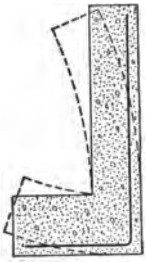


FIG. 45. DEFLECTION OF RETAINING WALL UNDER LOAD.

As concrete is not calculated to take tension and as steel is used for this stress, the knowledge of how structures deflect under load is important. If the student will analyze each structure with this in mind he will never be apt to place steel in the wrong face of members, reinforced for bending.

TABLE XII

DETAILS OF RETAINING WALL STEEL

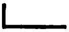
Size of rod	Number required	Length		Shape and detail	Mark	Remarks
		Ft.	In.			
⅜″Ø	184	5	3		Ra	Tension reinforcement
½″Ø	22	20	0	Straight	....	Ties

TABLE XIII

ESTIMATE SHEET FOR STEEL

1	2	3		4	5					
Size	No. pieces	Length		Shape of bend	Lineal feet of					
					⅜	½	⅝	¾	⅞	1
		Ft.	In.							
⅜″Ø ½″Ø	184 22	5 20	3 0	 Str.	966	440				

should be indicated by the estimator taking off quantities. Each bend costs some unit price and must be accounted for. A typical estimate sheet for such work might be shown in Table XIII. Columns 1, 2, 3 and 4 are filled in by the **estimator,** while the **extender** fills in the proper column under 5. The totals then give the **pricer** the size of rod, number of pieces, total bends of the size, and weight. The **unit price** can then be intelligently fixed.

Prob. 41*a*. Make an estimate sheet for the reinforcement required for the Column Footings in this building.

Prob. 41*b*. How many pounds of steel are required for these footings and the retaining wall?

Prob. 41*c*. If reinforcement can be bought at a price of 4½ cents per pound (base size), how much will the steel for Problem 41*b* cost if all extras on size, length, and tonnage are included (see Table X)? (Would you buy cut to length or in stock lengths?)

42. Placing Steel. The **placing** of steel in such a construction as the retaining wall for this building requires attention to the two important items of steel placement: namely, **stable location** and **proper spacing.** Fig. 46 illustrates the steel for a part of this wall in place. The wall of the form to which the steel is to be fastened is set and the steel is then fastened to it by **wiring to precast concrete blocks** as shown at (*a*), the horizontal part of the rod being rested upon similar concrete blocks, as at (*b*). If the **wall is wide** enough, both forms are set and braced and the **steel is wired to the ties** as shown in Fig. 47, the block (*b*) still being used. Where wiring is to be done at inaccessible points such as at (*a*) in Fig. 47, the wires should be strung through the form before it is placed. The **tie-rod** (*b*) is usually supported upon the wiring, and all the rods near the tie-wires are securely fastened to them giving the matted reinforcement sufficient stability during the placing of the concrete.

Prob. 42*a*. Draw an elevation of 20 feet of the retaining wall form to ½-inch scale, indicating the steel placement and blocks. (See Fig. 46.)

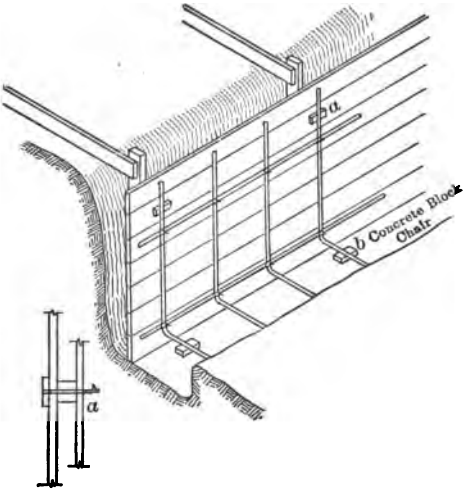


FIG. 46. WIRING THE STEEL TO ONE WALL OF A FORM.

As explained in connection with the matted steel for footings it is important that the reinforcement remain in its proper location during the placing of the concrete. The steel may be wired to one wall of a form by providing the proper spacers to keep it from coming into contact with the form.

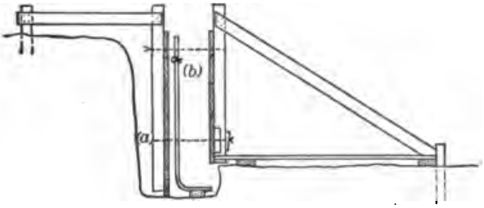


FIG. 47. WIRING THE STEEL TO BOTH WALLS OF A FORM.

Here the reinforcement is kept from touching the forms by fastening it to the tie wires at the proper distance from the forms.

43. Concrete Mixers. Mixers may be classified under two heads:

(*a*) The **batch** mixer.
(*b*) The **continuous** mixer (Plate VIII).

In the former the batch is mixed and discharged before another is started. In the latter the feeding and discharging take place continuously, an automatic measuring device proportioning the materials. The **batch mixer is preferred** and is customarily specified, although some continuous mixers have given satisfaction on some classes of work.

The batch mixers have two distinctly different methods of discharging: (1) a **tilting drum,** and (2) a **fixed drum discharging into a spout** which is turned at the outlet to receive the material from the inside of the mixer. They are loaded either from wheelbarrows directly into the drum, or from a loading **skip** operated mechanically. The drums are of several shapes from **cylinders** to **double cones, or cubes.** In these drums the materials are shoveled, cut and mixed by interior blades as in the circular types, or tumbled face to face in the cube type, until the concrete is thoroughly and **uniformly** mixed.

The different patented mixers have internal motion produced by blades, the more up-to-date machines having automatic locks to insure that the concrete is mixed for a minimum time, and controlling devices for the amount of water entering the drum. The **capacity** of the drums varies from **10** to **44 cubic feet** of dry materials. The dry capacity is 1½ times the wet capacity of mixed concrete.

Another type of mixer has been manufactured, called the **gravity mixer.** This consists of large funnels or pans suspended one over the other, both sides of which can be opened successively permitting the materials to flow from one pan into the other with only incidental mixing. Their operation is so inconsistent, as yet, that they are not to be recommended.

(*Perform Jobs No. 64, 65 and 66, Vol. II.*)

44. Machine Mixing. The operation of mixing can be divided into three distinct steps:

(*a*) **Loading.**
(*b*) **Mixing.**
(*c*) **Discharging.**

The loading or charging of the mixer for small jobs is done by wheelbarrows, either leading to the mixer by **runways** (Fig. 48) or to the **skip,** which is usually on the level of the grade. For larger work **overhead bins** are used, the material being **measured** and loaded into the mixer drums by means of **spouts.** The wheelbarrow method is dependent upon the personnel of the gang, and the efficient location of materials and runway, for its speed, while the bin-loading method can be made to reduce the time of loading to a practical minimum. In actual tests a Ransome ¼-yard mixer was loaded in **8 seconds,** unloaded in **12,** and required **54 seconds for mixing,** making a total of **1 minute and 10 seconds.** This is very good performance and cannot always be attained. The student is referred to p. 189 of Hool and Johnson's "Con-

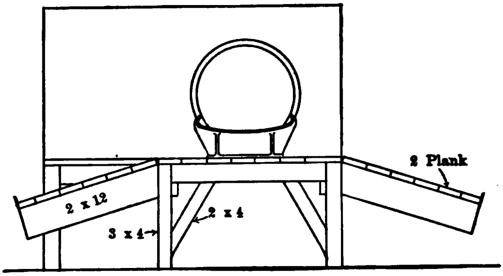


FIG. 48. RUNWAY TO MIXER.

Many methods have been devised to bring to a minimum the labor of feeding a mixer. These have all been consummated in the modern skip used in connection with most mixers. Where the skip is not used a double ramp is built at the feed end of the drum, so that the material may come uninterruptedly.

crete Engineer's Handbook" for a summary of the timing data on concrete mixers.*

The time required for mixing is more often too short than too long. Up to the limit of **30 minutes** no injury will be done to the concrete, but the customary time is a little over one minute. This item is much discussed at present and is dependent upon the condition of the mixer blades, the drum and the type of mixer employed. The time of mixing should be lengthened somewhat and less water used, than to take chances often indulged in, of excess water and careless speed, which practice nearly always results in some poor batches. Drum speeds have much to do with this question and in general it may be said that when a reputable mixer is used the contractor should adhere to the speeds specified by the manufacturers. Too great a drum speed will hold the material in the drum by centrifugal force, while a low speed will not give a thorough mixture.

The discharge of the mixer will be more rapid if the blades are reasonably **new** and of the **proper shape,** and the **drum is kept free from caked concrete.** These two items are responsible for more cases of inadequate mixing and slow discharge than any other.

45. Placing Concrete in Wall Forms. The transporting of concrete from the mixer to the form would ordinarily be done in wheelbarrows or carts on such a job as this. The barrows coming into use for this work are large enough to hold from **1½ to 2 cubic feet** of material and are so constructed as to allow the workmen to tilt them to a comfortable angle without spilling. (Fig. 49.) They are deep at the wheel end throwing a large part of the load upon the axle rather than upon the man. These are tracked upon plank runways sufficiently close to the form to permit dumping either sideways or forward. (Fig. 50.) It is often possible to so locate the mixer that it commands a considerable part of the wall. When this is true, it is advisable to **chute** the con-

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* See Eng. Record, Dec. 4, 1915, Mixer Actions, N. C. Johnson.

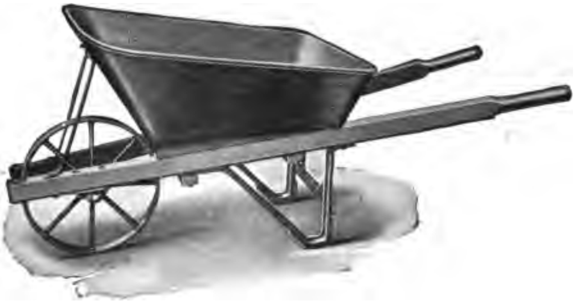


FIG. 49. STERLING CONCRETE WHEELBARROW.

The manufacture of metal wheelbarrows has been quite a help to concrete work. The barrow should be deep and should have a lip at the forward end so that the loss in carting will be reduced. Wooden handles are advised as against pipe handles because of the tendency of the pipe handles to rust and because they are extremely uncomfortable in cold weather.

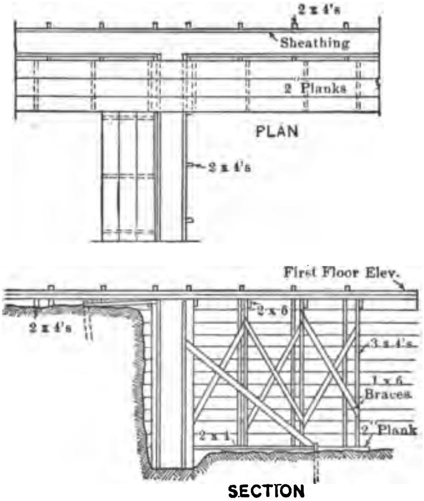


FIG. 50. PLANK RUNWAYS FOR CASTING WALLS.

Where walls must be cast at inaccessible points or where the mixing board cannot be placed adjacent to them, runways are provided from the platform or mixer to the forms. These often form quite an item of expense and must be carefully considered in estimating the work.

crete into forms by means of a wooden or steel chute attached to the discharge end of the drum. This chute can be moved to the location desired.

(*Perform Job No. 67, Vol. II.*)

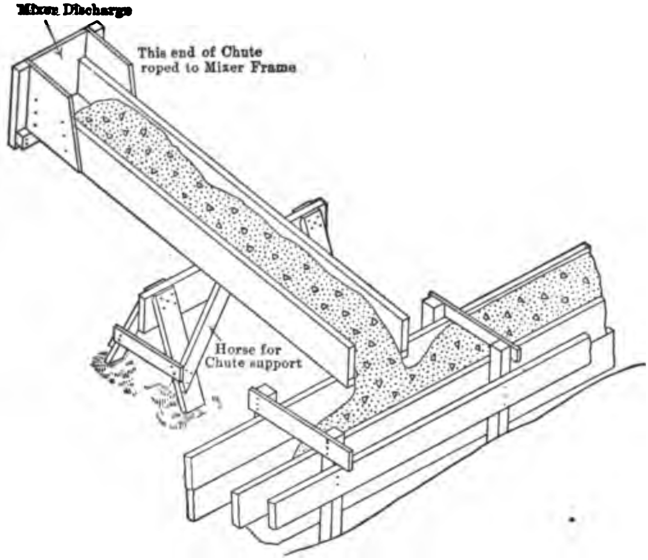


FIG. 51. CHUTING CONCRETE INTO FORMS.

Where the property will permit, the use of a small mixer on trucks with a wooden chute attached to the discharge end of the mixer is advised. This does away with considerable extra work in carting and avoids the loss of quite a percentage of the material. The chute should be made of 1¼-inch matched board properly braced and provided with a dash-board end as shown.

It is necessary to get quite a pitch to the chute, or to station men at it to keep the material moving along at the proper speed. (Fig. 51.)

The concrete should be deposited in **uniform** layers all around the wall, a **vertical joint** being previously **determined and provided** in case the work cannot be carried full around. Such a **stop board** is illustrated in Fig. 52, with **a lug** for the

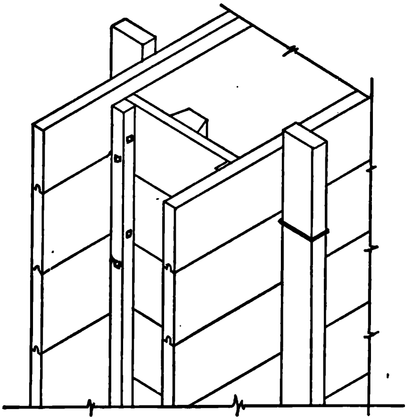


FIG. 52. STOP-BOARD FOR CONCRETE WALL.

When the method described for Fig. 51 is used the work will probably have to be stopped at various points in the wall. These boards should be set in the forms at points which will provide a day's concreting for the "gang" and the work should not stop until the wall is carried to a level surface.

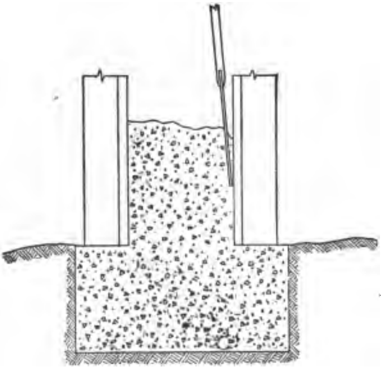


FIG. 53. POSITION OF TOOL IN SPADING.

To produce a good surface on a concrete wall enough mortar from the mix should be brought to the face to provide a flexible and dense mixture at the form. The concrete should be spaded well in the center first and then the spading tool should be forced down along the face of the form, pulled inward to allow the mortar to run in next to the form, and then removed.

proper bonding to future work. This method should always be followed where it is desired to build the wall its full height and in sections. The mixture for wall work should be of a quaky consistency (one which will gradually flatten out if dropped from the shovel) and is **spaded** thoroughly between the forms and next to each form face to release the entrained air and to allow the mortar to take its place next to the form. This insures a dense and smooth face. Fig. 53 illustrates

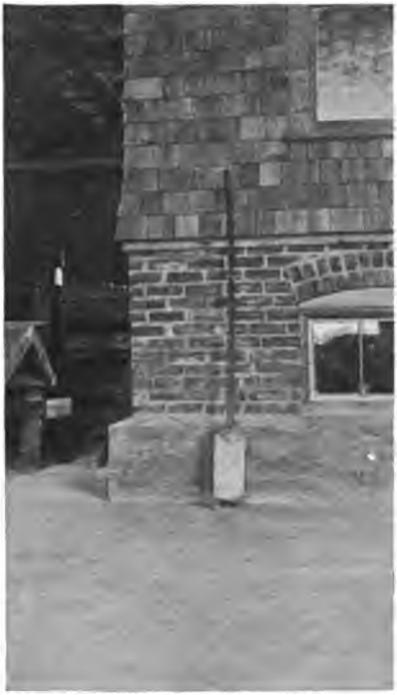


FIG. 54. TYPICAL SPADING TOOL.

This tool is made of a flat piece of steel about 4 inches × 18 inches and ¼ inch thick and is welded to a pipe handle. This is an ideal tool for the purpose explained under Fig. 53, but an ordinary square point shovel or spade will do equally as well in shallow forms.

the position of the spading tool for such work, and Fig. 54 a patented spading tool often employed. Too much stress cannot be laid upon proper spading, and the layers of deposited concrete should be of such a depth as to allow it to be done thoroughly and well.

When the wall is of such a height that it cannot be completed without stopping, there is danger of what are called **stoppage planes.** When concrete is placed and allowed to stand a while, a scum forms on the top of it, called **laitance.** This is a film of incoherent material mixed with set cement to which a bond cannot be established. It is always good practice to **pick** the top of the set concrete **an inch or two** in order to expose the firm concrete below. This surface should then be brushed with a stiff brush and wetted down. A thin coat of **cement grout** (mixture of cement and water to the consistency of heavy cream) is then applied, after which a thin layer of concrete is placed first. The concreting may then be resumed with fair assurance of good bond and a dense wall.

(Problem Job. No. 68, Vol. II.)

Prob. 45*a*. How far apart should the stop boards be placed in a 16-inch wall which is 8 feet high, if a batch mixer is used which will mix 10 cubic feet of dry materials at a time? (Mix 1–3–6.)

Solution. One foot of this wall will contain $\frac{4}{3} \times 8$ cubic feet $= 10\frac{2}{3}$ cubic feet.

From Table III, 1.10 barrels of cement, 0.46 cubic yard of sand, and 0.92 cubic yard of stone are required to make 1 cubic yard of concrete of a 1–3–6 mix. This makes 1.10 × 4 cubic feet of cement, 12.44 cubic feet of sand, and 24.88 cubic feet of stone, or 41.72 cubic feet of dry materials total. Therefore, to make 1 cubic yard of concrete, the mixer would have to turn out about 4 batches.

We will assume that the mixer can be loaded in 10 seconds, unloaded in 15 seconds, and that it takes 90 seconds to complete the mixing. This means that it will take 125 seconds, or approximately 2 minutes to turn out 1 yard of concrete. In a day of 8 hours the mixer will turn out material for 8 × 60 ÷ 2, yards of concrete. 240 cubic yards equal 1620 cubic feet of concrete. This divided by the amount of concrete in 1 foot of wall will give us approximately 150 feet. The stop boards should therefore be placed at least 150 feet apart.

Prob. 45*b*. Make a plan for the basement walls for the Lawlor Building and locate the stop boards, if the mixing is done by hand, in 1 bag mixes, requiring about 9 minutes each.

46. Remixed and Retempered Concrete. Sometimes the work is held up by accident or other delays and there is a desire to **use** the **left-over** batch of mortar or concrete. If the concrete has taken its initial set, or preliminary stiffening, it is sometimes reworked with a hoe. This process reduces the strength of the concrete and should not be allowed. Under ordinary conditions the set takes place in about **two hours,** but in **hot weather** it may be well upon its way in **45 minutes.** Wet concrete, however, may be in good condition after **six hours.**

47. Field Tests of Concrete. When the use to which concrete is to be put is such that absolute uniformity must be observed, it is customary to make either **field-moulded test specimens** from various batches, or to cut specimens from the construction. The latter are commonly called **structural specimens.** One of these will be found to vary greatly from the other at times, because of the difference in the method of casting. This is caused by difference in **static head** (amount of concrete above) in the mix, and by the subsequent protection afforded each. It will be well worth the student's time to read the report of **Committee C 9 of the American Society of Testing Materials, — June, 1917,** on this subject (appendix). Messrs. Hool and Johnson have added some interesting suggestions to this in their discussion of this report on p. 81 of their Hand-book.

48. Information on Agencies Destructive to Hardened Concrete. Soluble Alkali Salts in the soil have destroyed concrete, particularly where conditions of alternate wetness and dryness allow crystallization to break up the mortar, an action like that of frost. Dense concrete should be used to keep the water out.

Sea Water may be used for mixing water without detrimental effects. Caution: Salt, sea water, and calcium chloride should not be used when concrete is reinforced.

Note. — Concrete structures in sea water suffer no danger unless the sea gets in behind the outside **skin** that forms the surface of the concrete, especially between high and low tide where frost and abrasion expose the interior. The concrete in these structures should be dense.

Oils. Mineral oils and petroleum and engine oils have no effect. Oils with fatty acids produce injury.

Sewage. An ordinarily diluted, domestic sewage will have no injurious effect.

Electrolysis, which is caused by stray electric currents, will injure green concrete with steel embedded therein. The steel rusts, and the expansion on the rust causes cracks. The danger is not great. Non-reinforced structures are practically immune. Salt should not be used in structures subject to electrolysis.

Manure will injure the surface of green concrete.

Rusting of Reinforcement. The thin film of cement that surrounds the steel effectively protects it from rust. Steel in dry, porous concrete and in cinder concrete, is likely to rust.

Ground Water containing certain acids, like sulphuric acid, will destroy concrete.

Frost acting on concrete that has not set will freeze the water, and the ice crystals will force the mortar from the aggregate leaving a defective concrete.

49. Problems for Review.

Prob. 49*a*. Make a bill of materials for the runway construction for the Lawlor Building foundations. How many M feet of lumber are required?

Prob. 49*b*. If all the foundation walls are cast in two-wall forms, make the bill of materials for this form work. How many board feet of lumber are required per cubic yard? per cubic foot?

Prob. 49*c*. Illustrate the information given in Table XI by means of curves. If the strength of the boards vary as the square of their thickness, can you plot a curve for 2-inch planks?

Prob. 49*d*. If the foundation walls of the Lawlor Building are to be cast in one day, write a specification for the mixing plant, timing of mixes, and capacity.

CHAPTER VI

REINFORCED CONCRETE FRAME

The modern concrete building usually has a complete **concrete frame** with spandrel beams or curtain walls and sash, for exterior walls. This frame is made up of **slabs, beams, girders,** and **columns,** each of which is formed in different fashion.

50. Types of Column Forms. In this building the exterior walls carry the beams and slabs direct, while the **interior reactions** of the beams are carried by the columns. Columns have been made **rectangular, square, round,** and **elliptical** in section, but the first three are the most common. The **square** or **circular** column is usually used for the **interior** while the **rectangular** column serves in the walls and is known as a **wall column.** Wood was the natural forming material at first, but steel is gradually supplanting wood in the sphere of the circular column forms. The **steel form** has the distinct advantage of reusage while it has the disadvantage of high initial cost. In general the wood forms are **panels** or **column sides** made up of narrow sheathing strips to facilitate the reduction in size from floor to floor. These are **yoked** by 3 × 4's bolted together and **wedged,** or by the use of column clamps which will be described later.

51. Form Lumber. Lumber has been given definite trade names dependent upon the **size, shape,** and **position** it has. It is a distinct advantage to use these terms correctly and it is worth while to discuss them here. All pieces of lumber 1 inch thick are called **boards;** pieces $1\frac{1}{2}$ to 4 inches thick and from 8 to 16 inches wide are called **planks;** pieces $1\frac{1}{2}$ to 3 inches thick and from 3 to 6 inches wide are called **scantlings;** pieces larger than 4 × 6 inches, such as 6 × 6 or 8 × 10 are called **timbers.** When scantlings or planks are used for support horizontally and on edge they are termed **joists** or **stringers** and when timbers or scantlings are set vertically for column support they are called **posts, struts, shores,** or **jacks.** Pieces of boarding used to tie two or more pieces of other boards together to form a panel are called **cleats.**

The common terms applied to form lumber because of shape are:

(*a*) Dressed and matched (**D & M**).
(*b*) Tongued and grooved (**T & G**).
(*c*) **Ship-lap.**

The first two are similar in their moulding, a tongue and groove being used in each case for the matching. Ship-lap is illustrated in Fig. 19, p. 41. The manner of dressing or surfacing is indicated by the symbols **S1S1E, S1S2E, S2S, S4S.** S1S1E means that the lumber is surfaced on one side and one edge; similarly, S1S2E has one side and both edges planed; and when two or four sides are to be surfaced S2S and S4S are used.

It is necessary to know the finished size of lumber in order to determine form sizes correctly. 1-inch lumber, S1S or S2S, is from $\frac{7}{8}$ to $\frac{13}{16}$ inch thick, $1\frac{1}{2}$-inch lumber will size to $1\frac{5}{16}$ inches; and 2-inch lumber sizes to $1\frac{3}{4}$ inches in thickness. When boards are finished on two edges, they are $\frac{1}{2}$ inch narrower than the **nominal** dimension, making 1 × 6 become $\frac{13}{16}$ inch × $5\frac{1}{2}$ inches, and so on. 1 × 6 D & M will run $\frac{3}{4}$ inch thick by 5-inch **face,** and $5\frac{1}{2}$ inches overall. Likewise:

2 × 6 ship-lap ....$1\frac{5}{8}$ × 5 -inch face.....$5\frac{1}{2}$ inches overall.
1 × 6 T & G...... $\frac{13}{16}$ × $5\frac{1}{8}$-inch face.....$5\frac{1}{2}$ inches overall.
$1\frac{1}{2}$ × 6 T & G......$1\frac{5}{16}$ × $5\frac{1}{8}$-inch face.....$5\frac{1}{2}$ inches overall.
2 × 6 T & G......$1\frac{5}{8}$ × $5\frac{1}{8}$-inch face.....$5\frac{1}{2}$ inches overall.

In estimating form lumber one must calculate the nominal sizes to be used, not the exact sizes. Lumber is sold by the board foot, or the equivalent of a board 1 inch thick and

12 inches square, and the contractor pays for the lumber from which the piece is **originally cut,** plus any milling necessary. The amount of waste in lumber for concrete forms is usually **25 per cent** for sheathing, joists, and stringers.

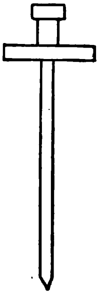


FIG. 55. DOUBLE-HEADED FORM NAIL.

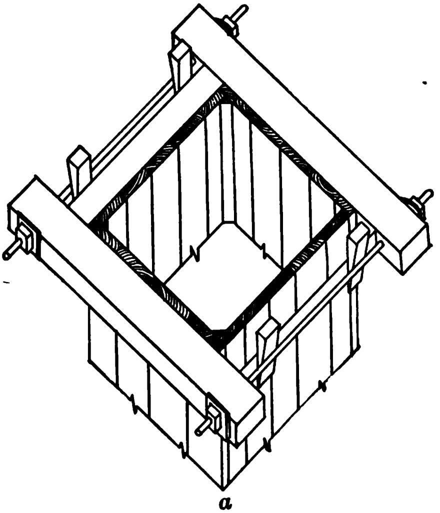
The removal of nails which have been driven full into the form is often the cause of waste of form lumber. Where the nail to be driven is not adjacent to the concrete this special nail offsets the possibility of driving nails full up to the head.

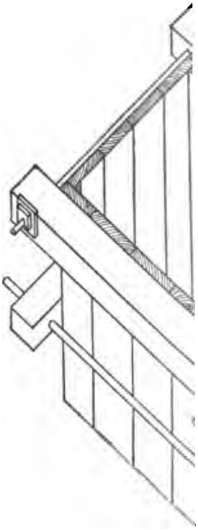
52. Nails. The improper use of nails or the use of improper sizes of nails will make much trouble in form stripping. If nails are used which are **too long,** the tendency is to **clinch** them. Should this be done to nailings which must come out for stripping, it will many times necessitate the destruction of forms which could be used again. If nails are driven **full to the head** in similar places, it also makes the removal of forms more difficult. To avoid this a **double-headed form nail** (Fig. 55) has been devised. This nail positively removes the possibility of such a mistake, if care is taken to see that the men use it for exterior nailing. The most important thing next to the strength of the forms is the **ease of stripping.** This can be accomplished by proper design in addition to the proper use of nails as described. Table XIV gives the nominal size, the length, and the number of nails per pound. The number of double-headed form nails will run about **10 per cent less.**

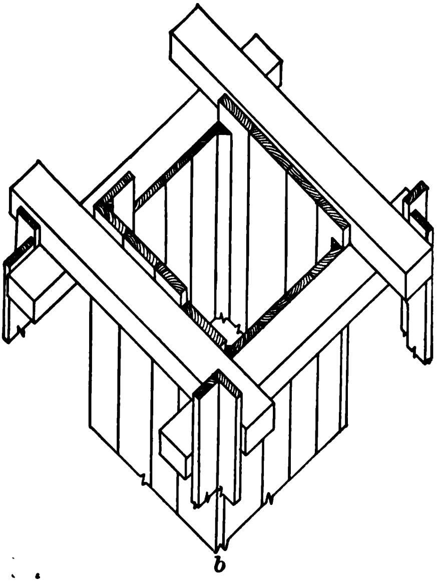
Prob. 52*a*. What size nail would you use to fasten 2 × 6 (nominal) ship-lap to a 4 × 4 cleat?

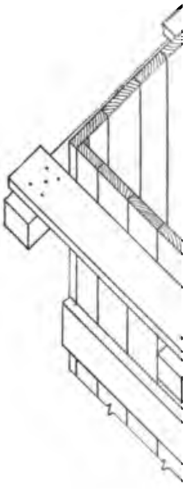
Solution. 2 × 6 ship-lap is actually $1\frac{5}{8}$ inches thick. A nail should ordinarily pass into the sustaining stick at least the thickness of the piece to be sustained. The length of the nail should therefore be at least $2 \times 1\frac{5}{8}$ inches $= 3\frac{1}{4}$ inches. A 12*d* (penny) nail could be used.

Prob. 52*b*. How large a nail would you advise for fastening ordinary $1\frac{1}{2} \times 6$-inch T. & G. (nominal)?







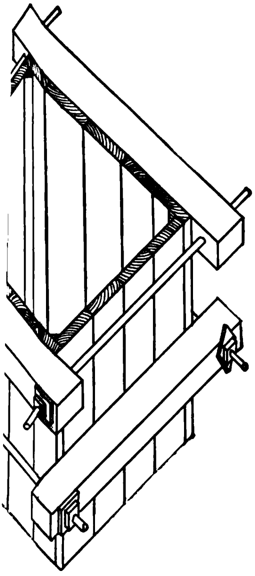


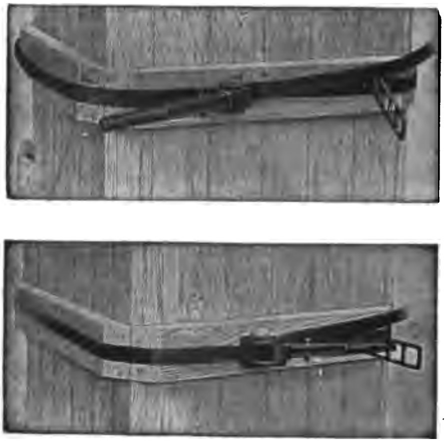
PLAT

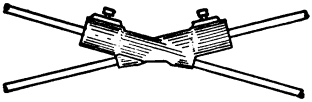
METHODS OF C

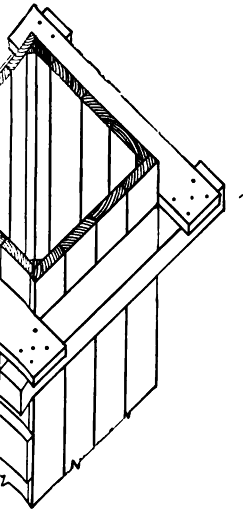
(*a*) Clips and wedges. (*b*) Blocking.

(*e*) Sterling form clamp. (*f*)









ATE IX.

COLUMN YOKING.

(*c*) Two-way clips. (*d*) Spiked yoke.

Universal round column clamp.

TABLE XIV

INFORMATION ON NAILS

Size	Length, inches	Number per pound
4*d*	1½	316
5*d*	1¾	271
6*d*	2	181
7*d*	2¼	161
8*d*	2½	106
9*d*	2¾	96
10*d*	3	69
12*d*	3¼	63
16*d*	3½	47
20*d*	4	31
30*d*	4½	24
60*d*	6	11

Prob. 52*c*. If you had 1 × 6 T. & G. boarding and 2 × 4 rough cleats and only 12*d* nails available, how would you overcome projecting nail points?

Prob. 52*d*. How many pounds of nails, classified by size, would be necessary to assemble the form for the west wall of the Lawlor Building as calculated in Problem 40*c*.?

Prob. 52*e*. Why should double-headed form nails not be used in surfaces adjacent to the cast concrete?

Prob. 52*f*. Why is the double-headed form nail made as it is? What keeps the nut-washer from driving up?

(*Perform Job No. 52, Vol. II.*)

53. Column Form Details. The variation in column form details, aside from the shape of the section of the column, occurs in the method of **yoking the form.** Plate IX shows some of the methods of yoking. Fig. (*a*) on this plate utilizes **bolts** for what are known as the **clips,** and the cleats for the other sides are **wedged** from these bolts to bring the section of the column into **uniform and plumb** alignment. Fig. (*b*) shows the simple method of **blocking.** Fig. (*c*) illustrates the yoke which operates by means of clips on each pair of opposite sides. In each of these cases the **lagging,** as the vertical sheathing is called, is fastened to the clips before erection. Fig. (*d*) is the ordinary **spiked** yoke. The student will notice that all the corners of the forms shown have **bevel strips.** This enables one to get better edges and avoids the possibility of chipped and unsightly corners upon the removal of the forms. A small opening is often left in the bottom of the column form for the purpose of cleaning it out. Figs. (*e*) and (*f*), show some of the patented clamping devices used today. Fig. (*e*), is the **Sterling Form Clamp,** manufactured by the Sterling Wheelbarrow Company, Milwaukee, Wis.; Fig. (*f*), the **Universal Round Column Clamp,** manufactured by the Universal Form Clamp Company, Chicago, Ill.

54. The Bending of Columns. A long column is a bar whose length is about **ten** or more times its least dimension. Failure in such columns usually occurs by excessive **stress in compression** due to sidewise buckling. Therefore, concrete columns must be reinforced with steel to take such possible bending. Vertical rods are also useful to transfer the stress over the weak places. If we had a short strut with a total load of 100,000 pounds on it, and its cross-sectional area was 100 square inches, the unit stress on the material of the column would be 1000 pounds per square inch. The average direct unit stress is still Load ÷ Area for long columns, but it would be much greater in compression on the concave side.

There are three types of column fastenings, namely: **two round ends, one round** and **one fixed end,** and **two fixed ends.** The third is the type we find almost always in building construction. Fig. 56 illustrates diagrammatically these three types of column ends. When the load is such that bending occurs, the columns would take the exaggerated shapes shown in Fig. 57. If we tried to show the stresses in these columns by a force diagram we would have the results shown in Fig. 58. The sections, *b–b*, would occur at the **points of contraflexure** or where the bending changes from right-hand deflection to left-hand deflection, or vice-versa.

These sketches show that provision must be made for excessive **compression on all sides** of the column, as one can never tell in which direction the column will bend. For this reason definite **empirical formulæ** for the strength of such columns (based upon test and experience), have been developed, which it will be worth while to study in some other connection.*

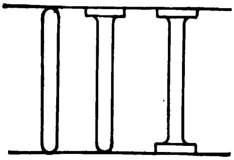


FIG. 56. THREE TYPES OF COLUMN ENDS.

Columns may have both ends free to rotate, both ends fixed, or one end fixed and one end free to rotate.

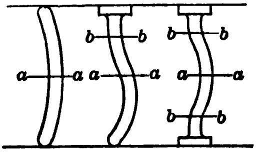


FIG. 57. BENDING IN COLUMNS.

When fixed-end columns bend points of contraflexure occur at *b*, whereas if the ends are free to rotate, the column bends freely from both ends as shown.

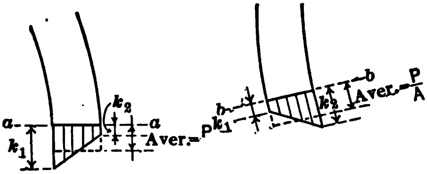


FIG. 58. STRESSES IN BENDING COLUMNS.

The concave side of a bending column is in compression, and the convex side is in tension. As the column is carrying a direct load which is causing this bending, the tension relieves the compression on the convex side and increases it on the concave side.

Prob. 54*a*. If a column of concrete were 16 inches square and the outside $1\frac{1}{2}$ inches were not calculated to take load, but merely as a protection to the steel, how many pounds would the core concrete sustain if each square inch could carry 650 pounds safely?

---

* See Taylor and Thompson's "Concrete, Plain and Reinforced," pp. 349–400, Third Edition.

Solution. Area of cross section of entire column is 16 × 16 square inches = 256 square inches.

The core would be (16 − 3 inches) × (16 − 3 inches) = 13 × 13 = 169 square inches. 169 × 650 pounds = 109,850 pounds.

Prob. 54*b*. A concrete column is designed for the wall of a concrete building, and is 16 × 32 inches. The load it is expected to carry on its core is 200,000 pounds. What is the stress on the core per square inch?

Prob. 54*c*. A concrete interior column is 26 inches in diameter and is reinforced with eight $1\frac{1}{8}''\varnothing$ rods vertically and the core stress allowed is 715 pounds per square inch. The vertical steel is allowed a value 15 times as great per square inch as the concrete. What load will the column sustain?

Prob. 54*d*. Compare the result obtained by multiplying the entire core area including steel area by 715, in Problem 54*c*, and adding to this the steel area × 14 × 715 pounds and that obtained by multiplying the net core area exclusive of the steel by 715 and adding the steel area × 15 × 715 pounds.

Prob. 54*e*.

If A_c = area of core concrete in square inches,
A_s = area of vertical steel in square inches,
S = stress in vertical steel per square inch,
C = stress in concrete core per square inch,
$\frac{S}{C} = 15,$

and P = total load on column,

prove that

$$A_c \times C + A_s \times 14 \times C = P = (A_c - A_s)\,C + A_s \times 15 \times C$$

by an actual problem.

55. Types of Reinforcement. Four general types of columns have been used, three of which use reinforcement. They are:

(*a*) Plain concrete columns (piers),
(*b*) Columns reinforced with longitudinal rods and ties,
(*c*) Columns reinforced with longitudinal rods and hoops or spirals,
(*d*) Columns reinforced with structural shapes.

The last three of these are illustrated in Fig. 59. In type (*a*), the plain concrete pier, the loads must be comparatively light or the column short. In type (*b*) the area within the core carries its proportion of the load while the vertical steel carries the balance. The same is true of types (*c*) and (*d*), but it is generally conceded that for any given mix of concrete the core of the spiral column can sustain a greater unit stress. The vertical steel in each of these again carries a definite stress per square inch which is a multiple of the value of the concrete stress. The 1½ inches of concrete which cover the core are protection only and are not calculated to carry any load, but undoubtedly do carry some. The student should continue this study in Taylor and Thompson's book before noted, or in Hool and Johnson's "Concrete Engineer's Handbook," as it is not the intention to go into the matter of concrete design in this text.

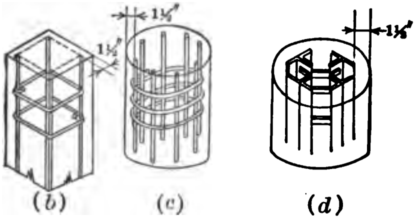


FIG. 59. TYPES OF COLUMN REINFORCEMENT.

In *b* the column is reinforced with longitudinal rods and ties; in *c*, with longitudinal rods and hoops or spirals; and in *d*, with structural shapes. The last named is called the Gray Column.

(*Perform Job No. 80, Vol. II.*)

56. Column Details. The details of concrete columns are an important part of the structural drawings. They are supposed to include a table giving sections and the steel required, and a detail of the typical columns for the building with such special column details as are necessary to make the drawings clear and complete.

57. Important Points in Form Detailing. It is much to the contractor's advantage to have his work so laid out that he can keep all his carpenters working efficiently and that all parts of forms will fit when ready for erection. In order to do this drawings must be made of all the forms. These drawings include an **assembly** sheet and **panel details** and each part is **numbered** or lettered and has its **definite location.** (Plates X, XI and XII.)

Mr. R. A. Sherwin, of the Aberthaw Construction Company, in a paper presented at a meeting of the American Concrete Institute recently, set forth the following admirable suggestions to the concrete form superintendent and draftsman:

> Joists and girts should be in as few lengths as possible, to save time in sorting on the job.
>
> Use stock sizes and lengths of lumber.
>
> Keep number of panels and pieces to a minimum.
>
> Provide for easy stripping.
>
> Allow clearance enough for slight inaccuracies in making up and erecting, swelling of forms, etc.
>
> Panels should be a whole number of boards in width, if possible, for convenience in making up.
>
> Units to be as big as can be handled, and joists used for panel cleats where possible.
>
> Beams to be handled as trough units, when the job is regular, and the units can be reused.
>
> Consider the use of floor domes or boxes where the beams are close together. In this way the slabs and beam sides are erected and stripped as a unit. When either of the last two systems is used the beams should be given a slight batter to facilitate removal.
>
> Provide for reshoring, if necessary.
>
> Have braces above the men's heads.
>
> When four-beam haunches occur at a column, consider making the four haunches as a unit, as a flat-slab construction.
>
> Consider the advisability of using steel forms.

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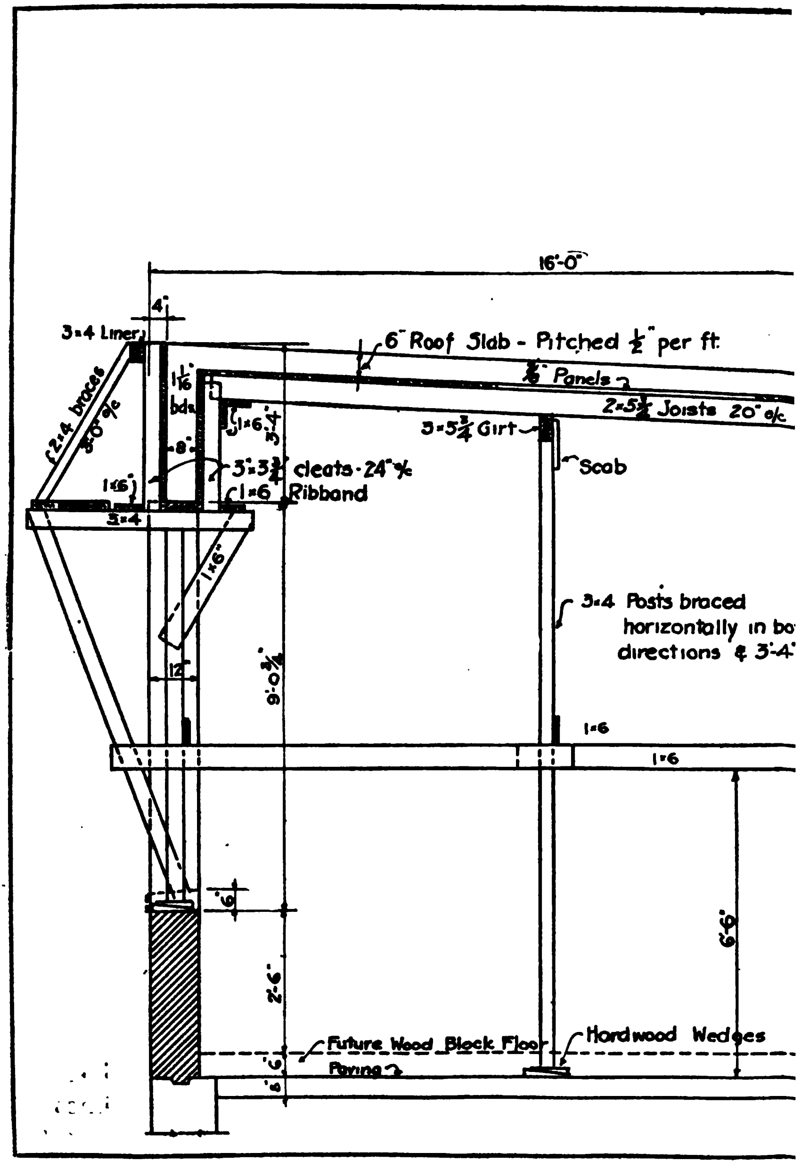

16'-0"
4"
3×4 Liner
6" Roof Slab - Pitched ½" per ft.
⅝" Panels
2×5½ Joists 20" o/c
3×5¾ Girt
Scab
1 1/16" bds.
1×6
8"
3"×3¾" cleats-24" o/c
1×6 Ribband
2×4 braces 5'-0" o/c
1×6
3×4
1×6
12"
9'-0¾"
3×4 Posts braced horizontally in bo
directions & 3'-4"
1×6
1×6
9"
6'-6"
2'-6"
6"
8"
Future Wood Block Floor Paving
Hardwood Wedges

P

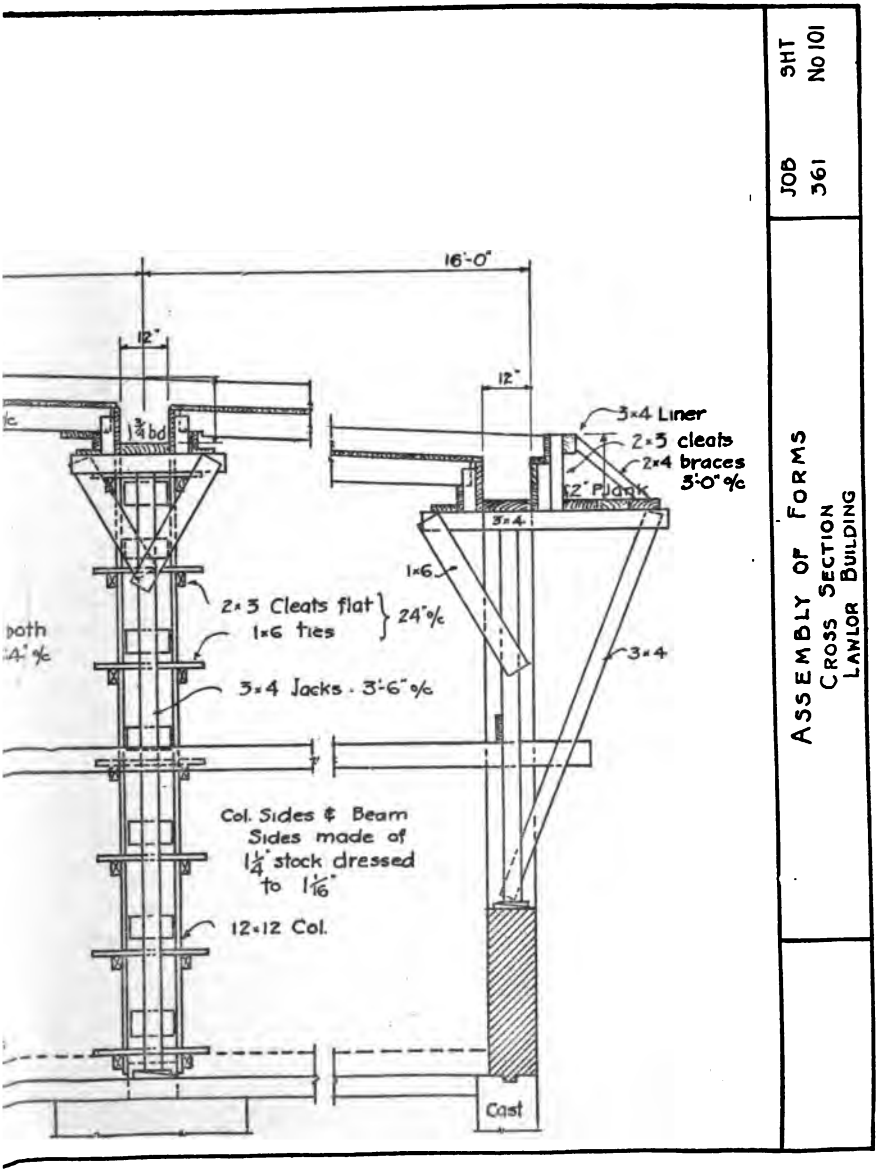
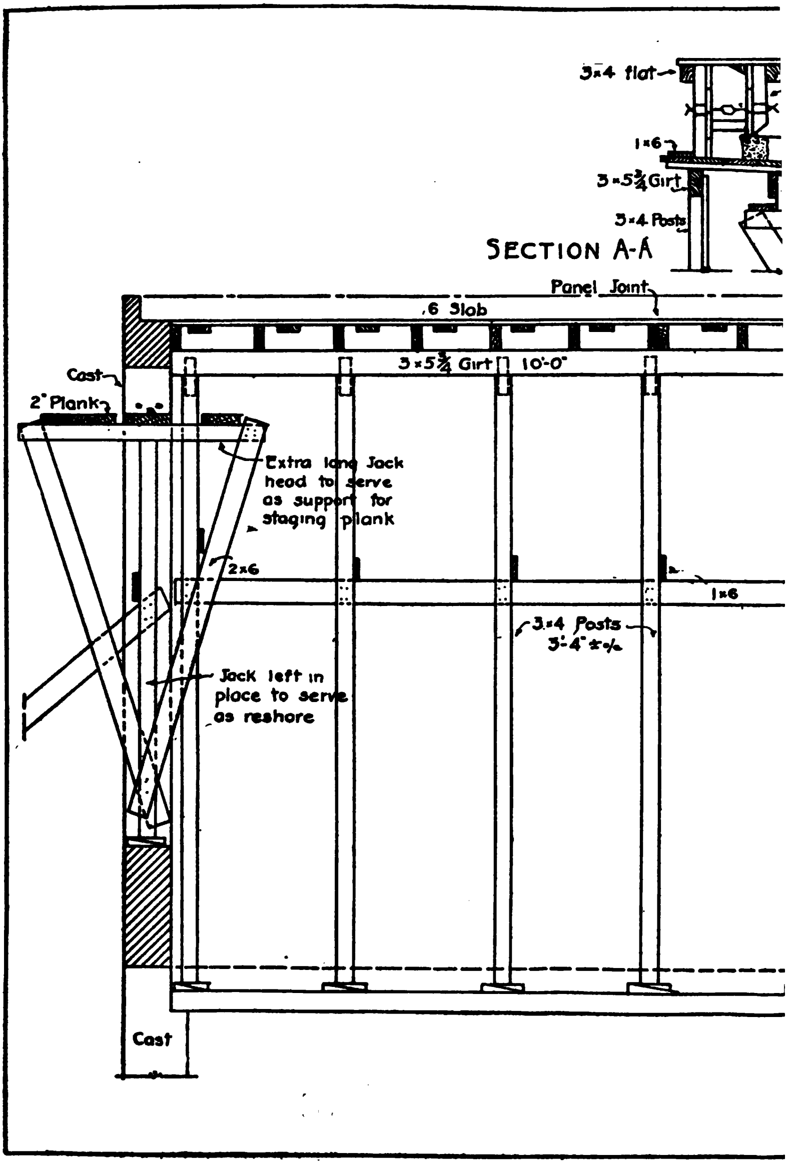
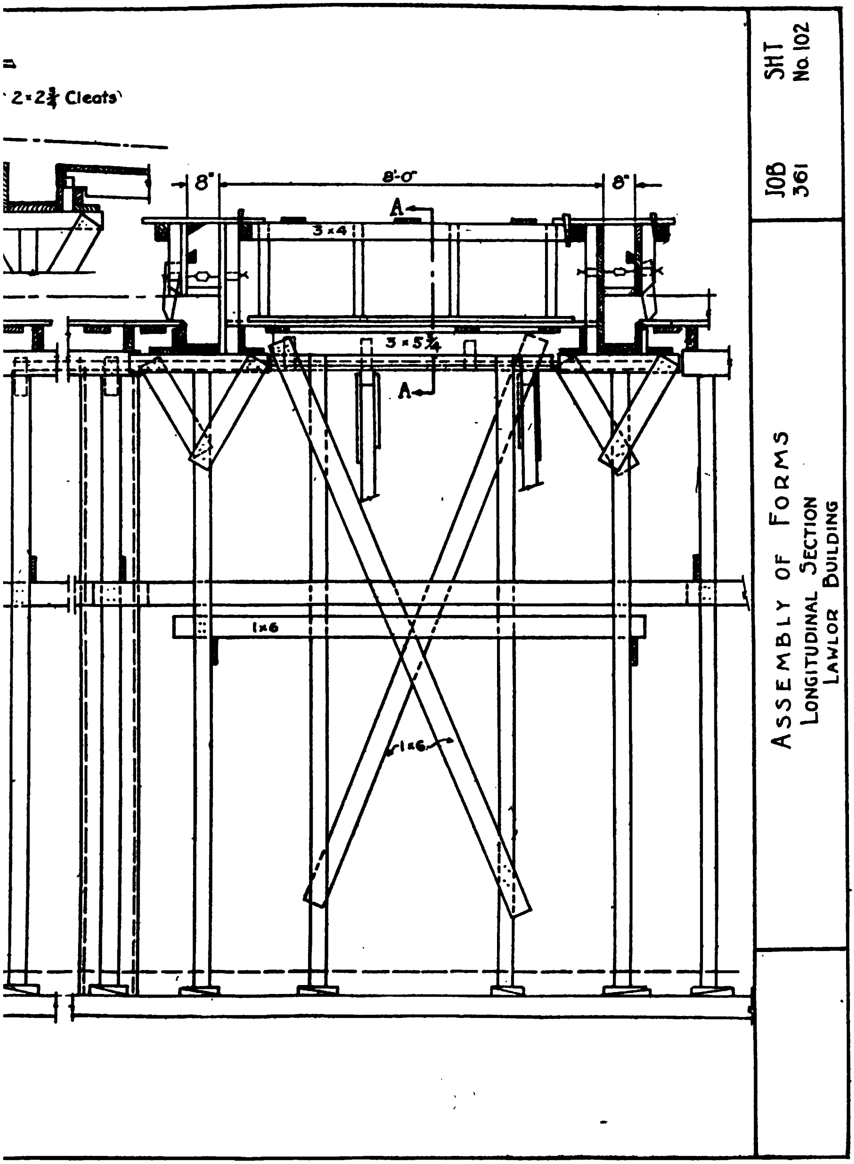
16'-0"
12"
12"
1¾ bd
3×4 Liner
2×3 cleats
2×4 braces 3'-0" o/c
2" Plank
3×4
1×6
3×4
2×3 Cleats flat
1×6 ties
24" o/c
3×4 Jacks · 3'-6" o/c
Col. Sides & Beam Sides made of 1¼" stock dressed to 1 1/16"
12×12 Col.
Cast
JOB 361
SHT No 101
ASSEMBLY OF FORMS
CROSS SECTION
LAWLOR BUILDING

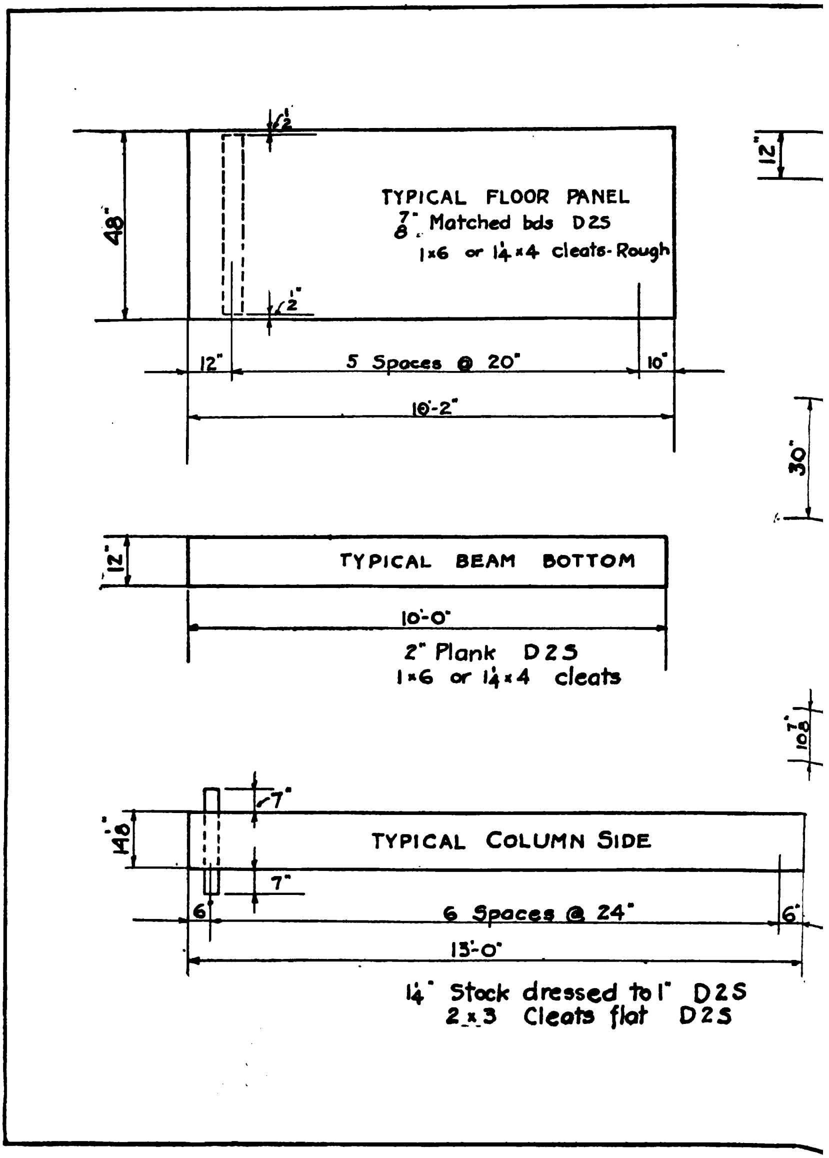
PLATE X.


3×4 flat
1×6
3×5¾ Girt
3×4 Posts
SECTION A-A
Panel Joint
6 Slab
3×5¾ Girt 10'-0"
Cast
2" Plank
Extra long Jack head to serve as support for staging plank
2×6
1×6
3×4 Posts 3'-4" ±
Jack left in place to serve as reshore
Cast

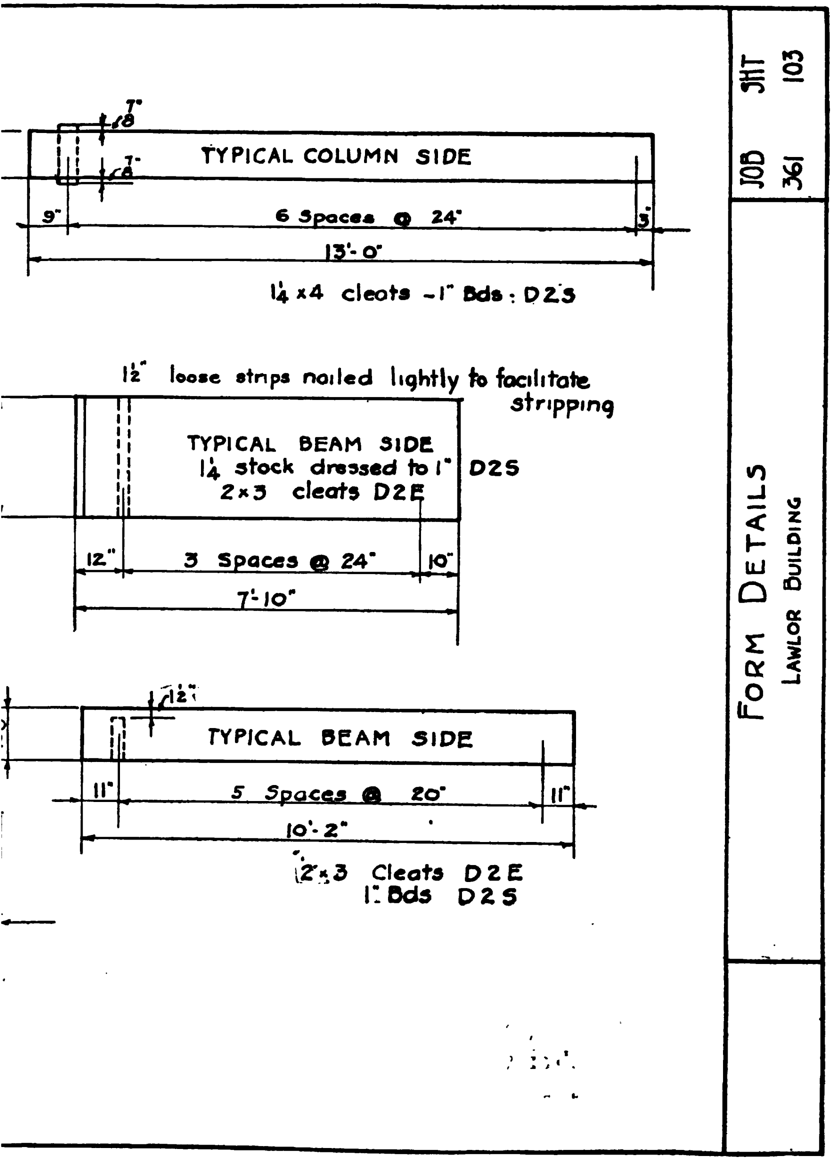
P.


2×2¾ Cleats
8"
8'-0"
8"
A
3×4
3×5¾
A
1×6
1×6
ASSEMBLY OF FORMS
LONGITUDINAL SECTION
LAWLOR BUILDING
JOB 361
SHT No. 102

ATE XI


TYPICAL FLOOR PANEL
7/8" Matched bds D2S
1×6 or 1¼×4 cleats-Rough
48"
1/2"
1/2"
12"
5 Spaces @ 20"
10"
10'-2"
TYPICAL BEAM BOTTOM
12"
10'-0"
2" Plank D2S
1×6 or 1¼×4 cleats
TYPICAL COLUMN SIDE
14⅛"
7"
7"
6
6 Spaces @ 24"
6"
13'-0"
1¼" Stock dressed to 1" D2S
2×3 Cleats flat D2S
12"
30"
10⅞"

PLATE


7"
/8
TYPICAL COLUMN SIDE
7"
/8
9"
6 Spaces @ 24"
3"
13'-0"
1¼ x 4 cleats - 1" Bds : D2S
1½" loose strips nailed lightly to facilitate stripping
TYPICAL BEAM SIDE
1¼ stock dressed to 1" D2S
2x3 cleats D2E
12"
3 Spaces @ 24"
10"
7'-10"
1½"
TYPICAL BEAM SIDE
11"
5 Spaces @ 20"
11"
10'-2"
2x3 Cleats D2E
1" Bds D2S
JOB 361
SHT 103
FORM DETAILS
LAWLOR BUILDING

E XII.

A system of symbols has been evolved by the Aberthaw Construction Company which makes the construction of forms very simple. ***B*** is used for **beam sides,** ***BB*** for **beam bottoms,** ***F*** for **floor panels,** ***C*** for **column sides,** ***H*** for **haunch forms,** and ***W*** for **wall panels.** The details are worked up on large sheets so divided that the prints can be cut up and placed into the hands of the carpenters. The form panel when complete is **stenciled** with its proper **mark** and stacked ready for use.

58. Lumber Sizes for Forms. Forms have been more or less standardized by the large contractors, and they use the following sizes:

1-inch stock, dressed to $\frac{13}{16}$ inch, for floor boarding.

$1\frac{5}{16}$-inch dressed planks are used for column and wall sheathing, and for beam sides.

$1\frac{3}{4}$-inch planks are used for beam bottoms.

The size and spacing of the joists, stringers, girts, and posts depends upon the load and rigidity required. To make a safe general rule for the size and spacing of these form supports would be difficult, but on the average joists are about 24 inches on centers, studs and posts 36 inches on centers, and the girts are placed as required. This is a question in which much study and experience is required and the student is referred to pp. 123 to 134 of Hool and Johnson's "Concrete Engineer's Handbook" for the discussion of the design of forms.

59. Special Details. This building involves its **special details** just as every other building. These are found in the method of forming the ends of the wall bearing beams, lintels, and skylight curb walls. The student is advised to study the assembly of these three special cases, as shown on Plates X and XI to determine the size of lumber used, the bracing and shoring of the forms, and any special items they show which vary from the typical.

Prob. 59*a*. Draw up two elevations of the forms for Column 1 of the Lawlor Building.

Prob. 59*b*. Study Plates X, XI and XII and make a schedule of the various sizes of lumber specified for the different members of the assembly.

Prob. 59*c*. Draw in plan the forms for the panels necessary to cast the first floor slab over the boiler and coal rooms.

Prob. 59*d*. Make assembly drawings for the forms for the reinforced concrete stairs leading from the first floor to the boiler room.

60. Bending in Beams and Slabs. Suppose we had six 2 × 6 inch planks resting upon each other and supported as shown in Fig. 60, and that we applied a load at the center as shown. The planks would **slide** upon each other and the ends would present the **offset** contour indicated. Suppose we bolted the planks together firmly so that they could not slide upon each other. The relation of the contour of the ends of the planks then would be as shown in Fig. 61. The **fibres** in the upper planks would then be **shortened**

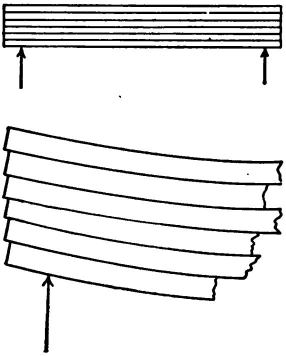


FIG. 60. BENDING IN BEAMS WITH HORIZONTAL SLIDING ALLOWED.

When the horizontal fibres of a beam are allowed to slide upon each other without restraint, the end of the beam assumes the contour shown.

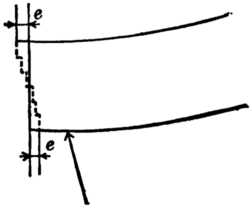


FIG. 61. BENDING IN TIMBERS.

When a beam bends and the horizontal fibres are not free to slide on each other, the upper fibres must shorten while the lower fibres lengthen. This produces compression in the top of a beam and tension in the bottom of a beam.

while those in the lower planks would be **lengthened,** by the distance "*e*." **Shortening** would cause **compression** while the process of **extension** would cause **tension.** The amount of either of these stresses would decrease from the extreme upper or lower fibre, as the case may be, to the **neutral axis,** or plane at which this stress would become zero. To illustrate this condition by a stress diagram we would have to draw such a Figure as 62. Within the **elastic limit** the stress would vary uniformly from the extreme fibre to the neutral axis. Of the two stresses, the **concrete** is usually expected to **carry** the **compression** while the **steel carries** the **tension** in a concrete beam.

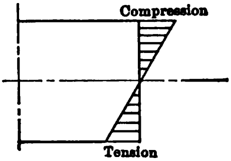


FIG. 62. STRESSES IN BEAMS.

This figure illustrates the tension and compression mentioned under Fig. 61.

(*Perform Job Nos. 81, 82 and 83, Vol. II.*)

61. Deflection and Stress. Concrete buildings usually are **monolithic** (of one piece) and act together in their various parts. This causes columns and adjacent slabs and beams to **fix** other slabs and beams, making the deflection take the shape shown in Fig. 63. The **points of inflection,** *I*, are so located that they divide the convex bending (negative) from the concave bending (positive). The bending is considered convex where the member bows upward, and concave where the member bows downward. By comparing Fig. 63 with Figs. 60 and 61 the student will observe that the **tension**

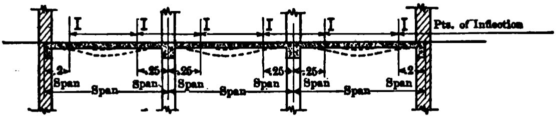


FIG. 63. BENDING IN CONCRETE SLABS.

Here we have the effect of the fixing action of the frame of the concrete building upon the slab. This restraint produces points of contraflexure at the points, *I*, which are ordinarily assumed to be located as shown.

passes from the lower part of the slab, at the points of inflection, to the upper part. Concrete is so constituted that it can take a certain amount of tension, but in actual practice it is not expected to take any. In places where tension occurs in reinforced concrete this stress is taken by steel embedded in the concrete. By means of the adhesion of the concrete and steel in the mass the latter is able to develop its strength. When the stress in the steel becomes high, **small hair cracks** occur in the tension side of the member, but these cracks are not necessarily a sign of a weakened structure, as the steel is performing its function at these points by means of bond with the concrete. We notice, therefore, in slab and beam details, that the **rods bend up** at the points of inflection, the steel following the same course as the tension.

Prob. 61*a*. If two points on the tension side of a beam which are 8 inches apart before loading are found to be $8\frac{1}{32}$ inches apart after the load is applied, how much is the elongation (e)? What is the elongation per inch (unit elongation)?

Solution.

$$\text{Elongation} = 8\tfrac{1}{32} - 8 = \tfrac{1}{32} \text{ inch.}$$
$$\text{Unit elongation} = \tfrac{1}{8} \times \tfrac{1}{32} = \tfrac{1}{256} \text{ inch} = 0.0039.$$

Prob. 61*b*. Unit stress divided by unit elongation is called the Modulus of Elasticity. A steel bar 30 feet long and 2 inches square in section, was subjected to a load of 48,000 pounds. The bar was found to be 0.143 inches longer. Compute the modulus of elasticity of the steel.

Prob. 61*c*.

If P = load on bar (pounds),
l = length of the bar (inches),
A = cross-sectional area of the bar (square inches),
E = Modulus of elasticity of steel,
and e = elongation (inches),
prove that $e = \dfrac{Pl}{AE}$.

62. Bonding Steel in Concrete. In order that the steel may take tension, the force must come into the steel from the concrete through the surface of the steel bars. This force is transferred to the body of the steel by surface bond, which is a natural state, and by mechanical bond, which is accomplished by the use of **lugs** of various kinds. (See Table IX, p. 84). The bond is expressed in **pounds per square inch** and is the resistance to the force tending to pull the rod from the concrete.

Tests for bond are usually made by pulling rods out of cylinders. In this case the concrete surrounding the rods is in compression when the test is under way. Bond resistance is also required of rods in concrete slabs and beams, where the concrete surrounding the rods is in tension (positive steel). It is not likely that the small amount of stress in the concrete will produce an important difference in the results of the tests in the two cases. Different elements in the moulding of the specimens, and others not well understood at present, however, may bring about a difference in the bond strength of these two kinds of tests.

Bond results from adhesive resistance, due to the grip as on a polished steel bar, and by sliding resistance due to the ordinary roughnesses of surface. After the former is overcome, the bar begins to **slip** at about **220 pounds per square inch** for 1–2–4 concrete which is sixty days old. This value is about **60 per cent** of the maximum bond. After slipping begins, the resistance further increases until a slip of 0.01 inch is reached. The resistance then decreases. The curve in Fig. 64 shows these facts.

Various factors influence the bond strength of rods. The size of the rod does not seem to affect the unit bond strength, which remains the same for rods of different diameters. **Rusted rods** show about **15 per cent** larger bond than clean ones. As to shape of the steel, **square bars** have about $\frac{3}{4}$ of the unit bond strength of the **round rods. Flat bars** are even **less efficient.** If the steel is **polished** it will show only **60 per cent of the strength** of a rod or bar with the ordinary mill surface. Any **oil** or **paint** which is allowed to get upon the surface of the reinforcement should be carefully removed, as it **impairs the bond** to a very large extent. **Deformed bars** illustrated in Table IX, p. 84, **add to** the **bearing area** against the concrete. The lugs, indentations, or twists may be so disposed that the cross section of the rods remains constant. Some **deformations** generally **have a wedging effect,** tending to **split** the concrete.

The relation of the first slip to the compressive strength of the concrete is about **13 per cent for plain rods,** while the

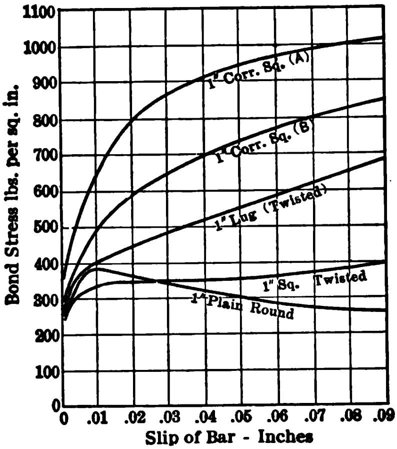


FIG. 64. RELATIVE ACTION OF PLAIN AND DEFORMED BARS IN BOND.

It is an established fact that deformed bars are somewhat more effective in bond than plain bars. Their great value, however, lies in the greater protection they afford against complete failure.

maximum bond occurs at about **19 per cent** of the **compressive strength.** Deformed bars show an initial slip not different from the plain bars, but after the slipping begins to take place the projections come into bearing, and the resistance rises and continues to increase after the plain bar has let go. However, **this amount of slip** accompanying high strength of bond **would not be permitted** in a concrete structure and the **advantage** of the **deformed bar** lies in its **greater factor of safety** against complete failure.

The relation between the size and the spacing of the lugs is important. If they are too close together, like a screw thread, the concrete between the lugs will shear out before the compressive strength of the concrete against them is reached. The maximum hold is obtained where the **spacing** of the lugs is about **ten times their projection.** The deformed bar which offers the greatest resistance to the first slip is the most favorable from the standpoint of strength. The twisted square bar, on account of its flat slope, is inferior.

Bond values increase with the **age** of the concrete and with its **richness.** Table XV gives the ultimate value, $\frac{1}{100}$-inch slip and the safe value for 1–2–4 concrete, twenty-eight days old, which has an average compressive strength of 2000 pounds per square inch.

(*Consult Job No. 47, Vol. II.*)

Table XV

BOND VALUES OF REINFORCEMENT

Type	Ultimate	$\frac{1}{100}$-inch slip	Safe value
Plain	400	240	80
Twisted	400	216	80
Corrugated	700	240	100

Prob. 62*a*. From a study of Fig. 64 make a table such as Table XV for the results given. Why is the factor of safety 5 for the plain and twisted types, and 7 for the corrugated bars?

63. Anchorage by Washers, Bends, and Hooks. Bars are often assisted in functioning in bond by **threading their ends** and fixing a washer and nut on them. This is an expensive practice, but it has been and is being used frequently. Fig. 65 shows such an anchorage. This only acts after the bar has begun to slip. When bars are brought to a stop in the ends of beams, or other places that require rigidity, the common practice is to bend the bar into a semicircular hook, with a radius of **two times the diameter** of the bar for the bend, and with a short length of bar beyond the bend. It should be well embedded in the concrete and a **short cross rod** adds considerably to its ability to resist slipping before the bar has begun to stretch. Fig. 66 shows this type of hooked bar and also the right angle bend, which is not as good as the hook.

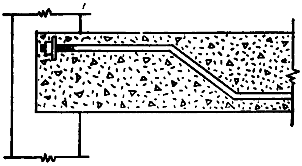


FIG. 65. ANCHORING BY MEANS OF A WASHER AND NUT.

This is expensive, but very effective. It is used frequently.

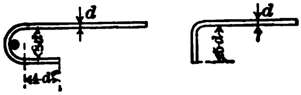


FIG. 66. HOOK AND RIGHT ANGLE BEND.

The former of these is the better to use, as it allows of less danger of pulling out, and does not impair the strength of the bar by the action of a sharp bend.

The length of the bent portion of this latter hook should be at least **5 diameters.**

(*Perform Job No. 48, Vol. II.*)

Prob. 63*a*. How many inches of steel would you allow to bend a hook on an inch bar?

Solution. The diameter of the semicircular arc of the bend would be $4d = 4 \times 1 = 4$ inches. The circumference of a circle is πd. In this case the circumference of a complete circle 4 inches in diameter would be $4 \times 3.14 = 12.56$ inches. Assuming that $\frac{1}{4}$ of the circumference is part of the body of the bar, as if straight, we must provide $\frac{1}{4}$ of a circumference and an additional length of $4d$ for the straight portion of the hook.

$$\begin{array}{lrl} 12.56 \div 4 & = & 3.14 \text{ inches} \\ 4d & = & \underline{4.00} \\ \text{Total} & & 7.14 \text{ inches additional rod.} \end{array}$$

(*Note.* — Lengths of rods should be expressed to the nearest ¼-foot, e.g., 3 feet 3 inches, 5 feet 9 inches, 12 feet 6 inches, etc.).

Prob. 63*b*. How many inches of additional steel would you allow for a ¾″⌀ rod bent into a hook? A right angle bend?

Prob. 63*c*. Make a table for the lengths required to bend hooks and right angle bends as follows:

Size	Hook	Rt. angle bend
1/4		
3/8		
1/2		
5/8		
3/4		
7/8		
1		
1 1/4		

64. Bending Reinforcement. When the steel is delivered on the site, it should be checked against the schedule, assorted into its proper divisions, and stored in raised racks in such a manner that the rods needed first may be easily reached.

On such a job as this, the steel frequently is delivered **bent to detail** and **marked,** but it is cheaper to have the steel delivered either in mill lengths or cut to length, after which it is bent on the job. If this is done, the equipment for such work must be considered. The student will note the various types of bends which the job entails, in addition to which are the bending of spiral coils from rod or wire. These latter, however, require a machine for accurate work and had much better be ordered bent to size.

Various types of bar bending devices have been produced among which are the Universal Bar Bender, and the power-operated bending machine manufactured by Kardong Brothers, Minneapolis, Minn. The student is referred to the catalogues of the Wallace Supplies Manufacturing Company, Chicago, Ill., the Waterloo Construction Company, Waterloo, Iowa, and Kardong Brothers for additional information on these devices. A simple apparatus is illustrated in Fig. 67. It is composed of a steel plate with holes arranged in the position required for the bends and into which steel pegs are placed. The bar is placed so as to be held by one peg while it is bent

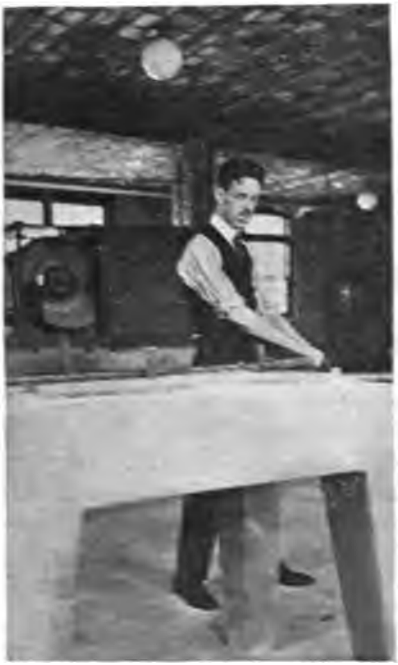


FIG. 67. BAR BENDING TABLE.

The bending of bars is very often done by hand on the job. The use of a piece of pipe to insure an accurate bend is advised. The bar is clamped to the table by placing it between steel pins set in a punched steel plate.

around another. A piece of iron pipe is slipped on to the rod and close up to the point of bending so as to insure a short bend. This method has been used on large constructions by prominent contracting engineers with success. It is necessary to be cautious to assure a bent rod which is **symmetrical** and in a **true plane.**

(*Perform Job No. 89, Vol. II.*)

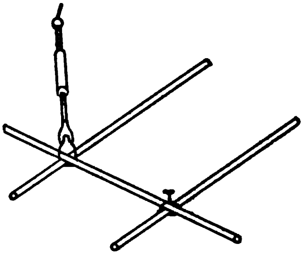


FIG. 68. THE CURRY TYER.

It is important to keep the steel in position as detailed on the plans. This has been accomplished by hand wiring, but the invention of this little tool has simplified the operation making more secure fastening at the same time.

65. Placing Reinforcing Steel. As previously intimated, a slight film of rust should not impair the strength of the bond, but **rust scales should be removed** with wire brushes, as they limit the bond strength attained. All steel should be placed in the correct position, and fastened by wiring or by some other appropriate fashion before any concreting is done. In this connection any loose bars which must be placed should be watched carefully so that they will not become dislocated. The steel should be wired at intersections. This may be done by bending light wires around the two bars with pliers. The **Curry Tyer** is a tool recently placed upon the market for this purpose and operates similarly to a ratchet drill or screw driver. The wire clip, with a loop on each end, is

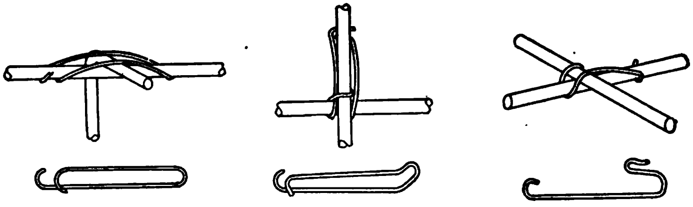


FIG. 69. BAR-TYS.

The invention of these simple wire appliances has made the location of steel in forms more accurate and the possibility of dislocation is practically done away with. They are so constructed that they snap on to the bars with great ease, the spring action holding the bars in place.

slipped under the rods and the hooks of the tool are placed into these loops. The wire can then be twisted by a quick upward jerk of the tool. Fig. 68 illustrates this tool and its use. Another type of tie is manufactured by the Concrete Steel Company and is illustrated in Fig. 69. In addition to securing one rod to another the **steel** must be **supported a definite distance from the forms.** Among the most commonly used devices for this work are the **beam spacers** and **easy chairs** manufactured by the Universal Form Clamp Company, Chicago, Ill., **Securo** slab and beam spacers, manufactured by the Metal Building Materials Company, of Chicago, and the chairs and spacers made by the Concrete Steel Company. The student will find some of these illustrated on Plate XIII.

66. Wire Fabric. For the reinforcement of slabs up to 14-foot span, walls and pavements, **wire fabric has shown** many valuable qualities. In general this material is made up of heavy wires called **carrier** wires crossed by lighter ones, called **tie** wires. In this way the reinforcing maintains its uniform spacing. Among the most common kinds are **Welded Wire Fabric,** manufactured by the Clinton Wire Cloth Company, and shown in Fig. 70, **Triangle Mesh Wire Fabric,** manufactured by the American Steel and Wire Company, Fig. 71,

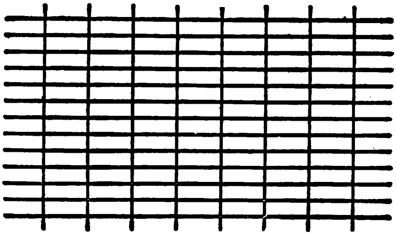


FIG. 70. WELDED WIRE FABRIC.

Wire fabric, in place of the ordinary form of bar reinforcement, is finding a great place in the concrete industry. It does away with the handling of many pieces, but has the disadvantage of decreased flexibility of design.

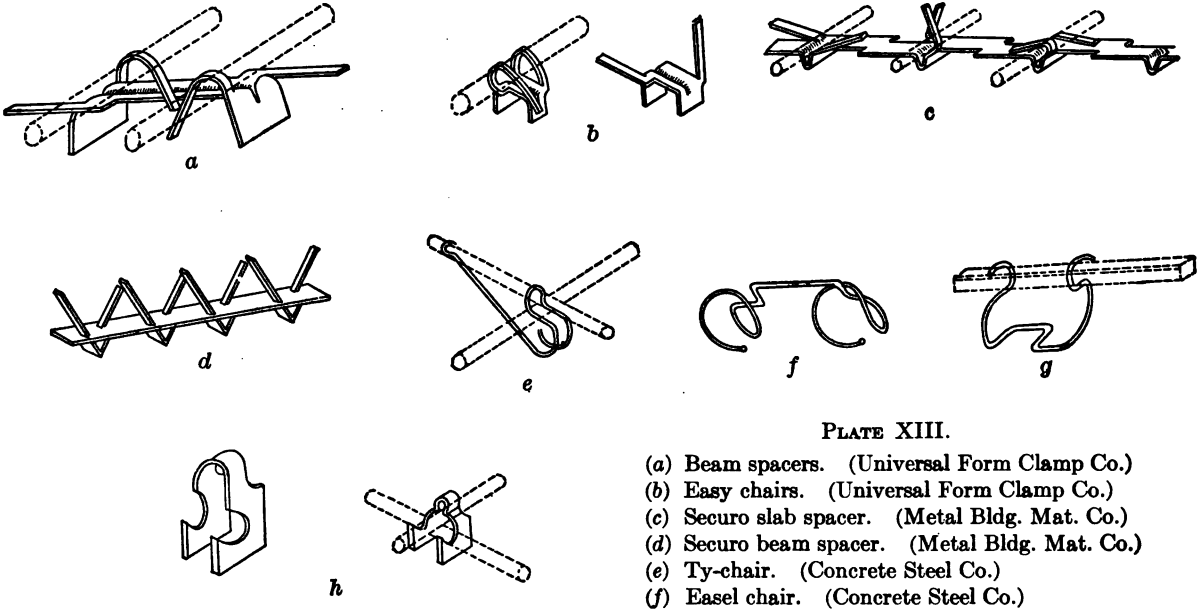


PLATE XIII.

(*a*) Beam spacers. (Universal Form Clamp Co.)
(*b*) Easy chairs. (Universal Form Clamp Co.)
(*c*) Securo slab spacer. (Metal Bldg. Mat. Co.)
(*d*) Securo beam spacer. (Metal Bldg. Mat. Co.)
(*e*) Ty-chair. (Concrete Steel Co.)
(*f*) Easel chair. (Concrete Steel Co.)
(*g*) Bar-chair. (Concrete Steel Co.)
(*h*) Chair lock. (Electric Welding Co.)

Unit Wire Fabric, furnished by the American System of Reinforcing, Fig. 72, and **Lock-Woven Steel Fabric** manufactured by the Page Steel and Wire Company, Fig. 73. Table XVI gives condensed data on these materials taken from the catalogues of the manufacturers.

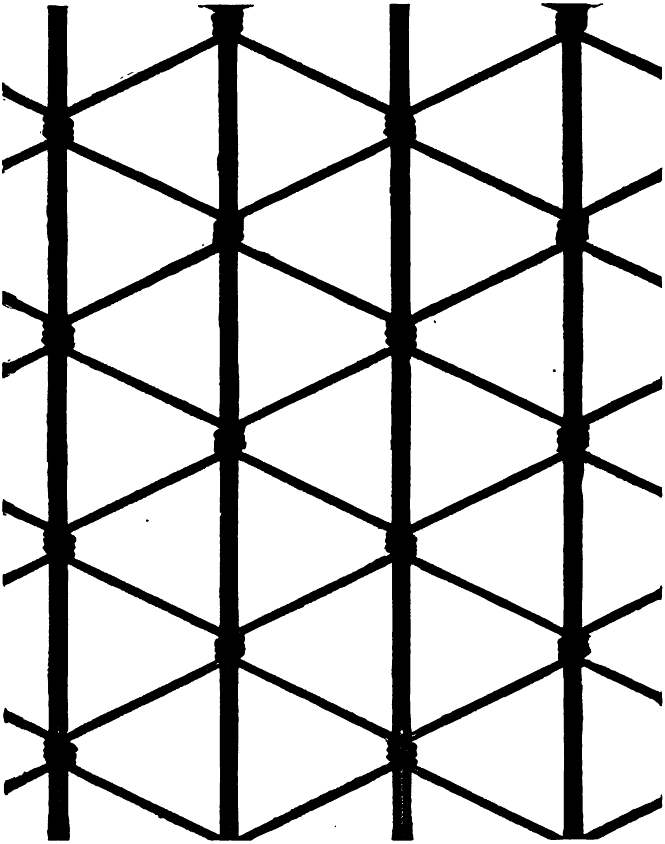


FIG. 71. TRIANGLE MESH REINFORCEMENT.

Prob. 66*a*. What is the cross-sectional area of the Unit Wire Fabric of nominal gauge 6–11? Of Welded Wire Fabric nominal gauge 5–9, 4-inch spacing? Of Triangle Mesh No. 168? Of Lock Woven Fabric No. 37½ B?

Prob. 66*b*. If a cross-sectional area of 0.07 was specified, what wire fabric would you use of each of the types given in Table XVI?

Prob. 66*c*. If a 6-inch slab were reinforced with Triangle Mesh No. 395, and you had to substitute Lock Woven fabric, what specification would you use?

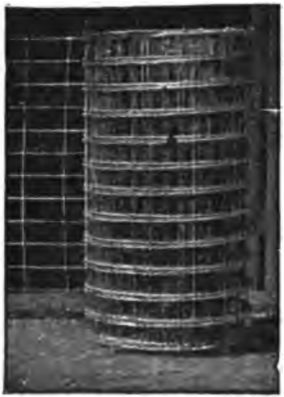


FIG. 72. UNIT WIRE FABRIC.

Prob. 66*d*. If a 4-inch slab reinforced with Welded Wire Fabric, gauge 3–8, 2-inch spacing, and the Building Law called for 0.6 of 1 per cent of steel in this case, would you pass the slab, if you were the building inspector?

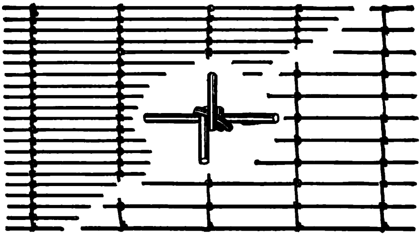


FIG. 73. LOCK WOVEN STEEL FABRIC.

Prob. 66*e*. If you had Unit Wire Fabric of 6–11 gauge delivered to a job to be incorporated into a 4-inch slab, what percentage of reinforcement would this be?

TABLE XVI
TRIANGLE (Δ) MESH FABRIC

Longitudinals spaced 4 ins.; cross wires No. 14 gauge spaced 4 ins.

Style number	Number and gauge of wires, each longitudinal, American Steel & Wire Company's steel wire gauge	Sectional area longitudinals, square inches per foot width	Total effective longitudinal sectional area, square inches per foot width	Approximate weight, lbs. per 100 square feet
032	1—No. 12 gauge	0.026	0.032	22
040	1— " 11 "	0.034	0.040	25
049	1— " 10 "	0.043	0.049	28
058	1— " 9 "	0.052	0.058	32
068	1— " 8 "	0.062	0.068	35
080	1— " 7 "	0.074	0.080	40
093	1— " 6 "	0.087	0.093	45
107	1— " 5 "	0.101	0.107	50
126	1— " 4 "	0.120	0.126	57
146	1— " 3 "	0.140	0.146	65
153	1— ¼ inch	0.147	0.153	68
168	1—No. 2 gauge	0.162	0.168	74
180	2— " 6 "	0.174	0.180	78
208	2— " 5 "	0.202	0.208	89
245	2— " 4 "	0.239	0.245	103
267	3— " 6 "	0.261	0.267	111
287	3— " 5½ "	0.281	0.287	119
309	3— " 5 "	0.303	0.309	128
336	3 - " 4½ "	0.330	0.336	138
365	3— " 4 "	0.359	0.365	149
395	3— " 3½ "	0.389	0.395	160

Longitudinals spaced 4 ins.; cross wires No. 12½ gauge spaced 8 ins.

Style number	Number and gauge of wires, each longitudinal, American Steel & Wire Company's steel wire gauge	Effective sectional area of cross reinforcement, square inches per foot width	Effective longitudinal sectional area, square inches per foot width	Approximate weight, lbs. per 100 square feet
041R	1—No. 12 gauge	0.014	0.041	21
049R	1— " 11 "	0.014	0.049	24
058R	1— " 10 "	0.014	0.058	28
067R	1— " 9 "	0.014	0.067	31
077R	1— " 8 "	0.014	0.077	35
089R	1— " 7 "	0.014	0.089	40
102R	1— " 6 "	0.014	0.102	44

150, 200 and 300 foot rolls; 16, 20, 24, 28, 32, 36, 40, 44, 48, 52 and 56 inches wide.

TABLE XVI (*Cont.*)

WELDED WIRE FABRIC

Gauge of longitudinal wires W. & M. gauge	Diameter of longitudinal wires, inches	Area of one longitudinal wire, square inches	Gauge of transverse wires, W. & M. gauge	Spacing of transverse wires, inches	Area per foot of width in longitudinal wires only				
					Spacing of longitudinal wires				
					2 inches	3 inches	4 inches	5 inches	6 inches
0	0.307	0.074	6	16	0.443	0.295	0.221	0.177	0.148
1	0.283	0.063	6	16	0.377	0.252	0.189	0.151	0.126
2	0.263	0.054	8	16	0.325	0.217	0.162	0.130	0.108
3	0.244	0.047	8	16	0.280	0.187	0.140	0.112	0.093
4	0.225	0.040	9	16	0.239	0.160	0.120	0.096	0.080
5	0.207	0.034	9	16	0.202	0.135	0.101	0.081	0.067
6	0.192	0.029	10	16	0.174	0.116	0.087	0.069	0.058
7	0.177	0.025	10	16	0.148	0.098	0.074	0.059	0.049
8	0.162	0.021	10	12	0.124	0.082	0.062	0.049	0.041
9	0.148	0.017	11	12	0.104	0.069	0.052	0.041	0.035
10	0.135	0.014	12	12	0.086	0.057	0.043	0.034	0.029

Longitudinal wires		Transverse wires		Based on longitudinal wires only in 1 foot of fabric width	Description of rolls		
Spacing, centers	Size	Spacing, centers	Size	Sectional area, square inches	Length, feet	Width, inches	Weight, lbs.
Inches	No.	Inches	No.				
2	3	16	8	0.2798	150	62	777
3	3	16	8	0.1865	150	86	746
3	4	16	9	0.1594	150	86	636
4	3	16	8	0.1399	150	86	579
3	5	16	9	0.1346	150	86	545
3	6	16	10	0.1158	200	86	623
4	5	16	9	0.1009	150	86	425
3	7	16	10	0.0984	200	86	537
4	6	16	10	0.0868	200	86	486
3	8	12	10	0.0824	200	86	473
3	8	8	10	0.0824	200	86	509
4	7	16	10	0.0737	200	86	420
3	9	12	11	0.0690	200	86	395
4	8	12	10	0.0618	200	86	378
4	8	8	10	0.0618	200	86	411
4	9	12	11	0.0518	200	86	318
5	12	9	12	0.0209	400	102	385

TABLE XVI (*Cont.*)

UNIT WIRE FABRIC

Gauge of carrying wires	Gauge of cross wires	Distance center to center		Sectional area in square inches per foot width
		Carrying wires	Cross wires	
		Inches	Inches	
11	11	6	6	0.023
10	10	6	6	0.028
9	11	6	6	0.035
9	11	4	12	0.05
9	11	3	12	0.07
8	11	4	12	0.062
7	11	4	12	0.074
6	11	4	12	0.087
5	11	4	12	0.10
4	11	4	12	0.12
3	11	4	12	0.14

LOCK WOVEN STEEL FABRIC

All longitudinals spaced 3 ins.; transverse wires, 12 ins.

Fabric No.	No. wires each longitudinal	Size wires in each longitudinal	Sectional area each longitudinal	Gauge cross wire	Area of cross section per foot width of fabric, sq. in.	Weight per 100 square feet
14 A	1	14	0.0050	14	0.0201	11.04
13 A	1	13	0.0066	14	0.0263	12.91
12 A	1	12	0.0088	14	0.0350	15.85
12 B	1	12	0.0088	12	0.0350	18.44
11 A	1	11	0.0114	14	0.0456	17.47
11 B	1	11	0.0114	12	0.0456	20.34
9½A	1	9½	0.0156	14	0.0624	27.72
9½B	1	9½	0.0156	12	0.0624	30.75
9 A	1	9	0.0173	14	0.0691	28.60
9 B	1	9	0.0173	12	0.0691	31.78
29 A	2	9	0.0346	14	0.1382	55.58
29 B	2	9	0.0346	12	0.1382	59.60
39 A	3	9	0.0516	14	0.2064	81.95
39 B	3	9	0.0516	12	0.2064	87.46
7½A	1	7½	0.0226	14	0.0904	37.50
7½B	1	7½	0.0226	12	0.0904	40.42
27½A	2	7½	0.0452	14	0.1809	70.88
27½B	2	7½	0.0452	12	0.1809	76.04
37½A	3	7½	0.0678	14	0.2713	105.19
37½B	3	7½	0.0678	12	0.2713	111.10
7 A	1	7	0.0246	14	0.0984	39.48
7 B	1	7	0.0246	12	0.0984	42.84
27 A	2	7	0.0492	14	0.1969	77.54
27 B	2	7	0.0492	12	0.1969	82.32
37 A	3	7	0.0738	14	0.2953	114.32
37 B	3	7	0.0738	12	0.2953	120.51
23 B	2	3	0.0935	12	0.3740	142.88

Regular rolls 150 and 300 feet in length.

Made in widths of any multiple of 3 inches from 18 to 54 inches.

Prob. 66*f*. How would you specify the substitution of $\frac{1}{4}''\varnothing$ rods to replace 0–6, 2-inch spacing, Welded Wire Fabric in a 6-inch slab?

67. Wire Mesh. Contrasted to the wire fabrics, which are woven, are the **expanded wire-mesh sheets.** These are made by various processes, all of which use standard gauge sheets, punched, pressed and expanded in machines. The shape of the meshes varies, some utilizing the principle of two-way reinforcement by means of a diamond mesh, while others depend upon the stamped rib for reinforcement, the intermediate parts being used as spacers and ties only. Plate XIV illustrates several kinds of wire-mesh sheets and Table XVII gives the data for them taken from the manufacturers' catalogues.

TABLE XVII

INFORMATION ON WIRE MESH

Name	Manufacturer	Size of sheet		Sheets per bundle or crate			Square feet per bundle or crate			Gauges	Sectional area as reinforcement
		Width	Length								
EUREKA	Northwestern Expanded Metal Co.	21″	8′	9			126			26	
		22″					132			24	
										22	
T-RIB CHANELATH	Northwestern Expanded Metal Co.	4″ to 48″ by 4″ intervals	By ft. from 3′ to 12′	No. ordered crated						24	0.244
										26	0.183
										28	0.152
SELF-SENTERING	General Fireproofing Co.	29″	4′	12			116				
			5′				145				
			6′				174			All	
			7′				203			lengths	
			8′				232			in	
			9′				261			24	0.277
			10′	10			242	290		26	0.208
			11′	8	10		213	266	319	and	
			12′				232	290	348	28	0.173
				24	26	28	24	26	28		
				Gauges							

TABLE XVII (*Cont.*)

Name	Manufacturer	Size of sheet		Sheets per bundle or crate	Square feet per bundle or crate				Gauges	Sectional area as reinforcement
		Width	Length		8′	10′	12′	16′		
Steelcrete	Consolidated Expanded Metal Co.	6′ 0″	8′ 0″ 12′ 0″ and 16′ 0″ No. 9 gauge 10′ 0″ also	10	480		720	960	13	0.075
		6′ 9″		7	378		568	757		0.10
		5′ 3″			295		442	590		0.125
		7′ 0″		5	280	350	420	560	9	0.15
		6′ 0″			240	300	360	480		0.175
		5′ 3″			211	263	316	421		0.20
		4′ 0″			160	200	240	320		0.25
		7′ 0″		2	112	140	168	224		0.30
		6′ 0″			96	120	144	192		0.35
		7′ 0″			112		168	224	6	0.40
		6′ 3″			100		150	200		0.45
		5′ 9″			92		138	184		0.50
		5′ 3″			84		126	168		0.55
		4′ 9″			76		114	152		0.60
		5′ 9″		1	46		69	92	1	0.75
		4′ 3″			34		51	68		1.00

Name	Manufacturer		Size of sheet		Sheets per bundle or crate	Square feet per bundle or crate				Gauges	Sectional area as reinforcement
			Width	Length							
Corr-Mesh	Corrugated Bar Co.	5/16″ rib 3″ o.c.	18″	8′	100	1200				24	
				12′		1800				26	
		3/4″ rib 3¼″ o.c.	13″	6′		650				28	
				8′		867				in both widths	
				10′		1083					
				12′		1300					
Trussit	General Fireproofing Co.		19″	8′	10	126				24, 26, or 27	
				10′		158					
				12′		189					
Herringbone BB	General Fireproofing Co.		20¼″	8′	15	204				22, 24, 26 or 27	
Hyrib	Truscon Steel Co.	1½″	14″	6	8	56	74	92	112	24 26	0.236 0.177
		15/16″	24″	8′		96	128	160	192	24 26 28	0.219 0.164 0.137
		13/16″	16″	10′ or 12′	16	128	171	213	256	24, 26, and 28	
		3/8″	20″			160	212	266	320		
		Rib lath	21″	8′	12		168				
		Rib				6′	8′	10′	12′		

TABLE XVII (*Cont.*)

Name	Manufacturer	Size of sheet		Sheets per bundle	Square feet per bundle	Gauges	Sectional area as reinforcement
		Width	Length				
RIBPLEX	Berger Manufacturing Co.	24"	By ft. from 4' 0" to 12' 0"	Per order		24	0.198
						26	0.148
						28	0.124
						All lengths	
GF EXPANDED METAL	General Fireproofing Co.	3' 0" 4' 0" 5' 0" 6' 0"	6' 8' 9' and 10' 8"	Per order		10	0.176
		4' 0" 5' 4"				10	0.265
		3' 0" 4' 0" 6' 0"				10 and 12	0.353 0.150
		3' 0" 4' 0" 6' 0"	6' and 8'			12 12	0.194 0.246

(*Perform Job No. 51, Vol. II.*)

Prob. 67*a*. Specify the Steelcrete, T-rib Chanelath, Self-Sentering, and GF Expanded wire mesh to give the same area of reinforcement in a 6-inch slab as $\frac{1}{2}''\varnothing$ rods 10-inch o.c. would give.

Prob. 67*b*. How would you specify the wire mesh for a floor slab made up of panels of 7-foot span to cover an area 70 feet by 64 feet?

68. Problems for Review.

Prob. 68*a*. What difference is there in the way in which a column carries load and the way in which a beam carries load?

Prob. 68*b*. Would a 12 × 12 pier 6 feet high be considered a column? Why?

Prob. 68*c*. If the columns in this building carry a load of 44,000 pounds, what percentage of this load is carried by the steel, and core concrete, respectively? What is the core stress per square inch?

Prob. 68*d*. If the slab over the boiler and coal rooms of this building were to be reinforced with wire fabric, how would you specify it?

Prob. 68*e*. Make a plan of the slab mentioned in Problem 68*d*, and locate the fabric reinforcement.

Prob. 68*f*. Work up an Assembly Plan and Section of the forms for the support of the slab in Problem 68*d*.

Prob. 68*g*. Make an estimate sheet for the lumber required to erect the forms shown on your plan and section worked up in Problem 68*f*. How many board feet of lumber are required? How many per cubic yard of concrete? How many per square foot of floor?

Prob. 68*h*. Make an estimate sheet for the lumber required for forming the roof of the Lawlor Building. How many board feet are required? How many per cubic yard of concrete? How many per square foot of roof?

CHAPTER VII

ERECTION OF REINFORCED CONCRETE

69. Types of Slab Construction. In the **beam** and **girder** type of construction, of which our building is an example, several types of slab construction have been developed. The four important types from the point of frequency of use, besides the **structural steel and slab** type, are:

(*a*) The **one-way slab.**
(*b*) The **two-way slab.**
(*c*) The **tile-joist slab.**
(*d*) **Slabs using made-up floor-cores** of metal or gypsum.

The one-way slab is illustrated in the roof construction of our building. (Plate III.) The reinforcement **carries** the **load in one direction** only, in this type. In the two-way slab, reinforcement is provided in **two directions,** each carrying its proportional part of the load. This type is illustrated in Fig. 74. The tile-joist slab may also be either one- or two-way. In this slab the tile are placed **directly** upon the forms, spaced **4** or **5 inches** apart. The steel is then placed in the channels. The concrete is cast over the whole, and is carried from **2** to **4 inches** thick upon the tile. When the slab is of the one-way variety, the tile are placed end for end, the concrete forming beams, which are commonly called **joists.** When the two-way variety is used, the beams run in **both** directions. Fig. 75 * is a plan and section of the one-way tile joist slab, and Fig. 76 * is a similar plan and section for the two-way slab. Note that the slab is indicated as:

"4-inch tile plus 2-inch Concrete."

(Perform Job No. 90, Vol. II.)

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* Furnished through the courtesy of the National Fireproofing Company.

The **floor-core** or **dome slab** followed directly upon the use of the tile-joist slab and embodies a similar principle. It is a much lighter construction however, as will be noted from an examination of Fig. 77, which indicates

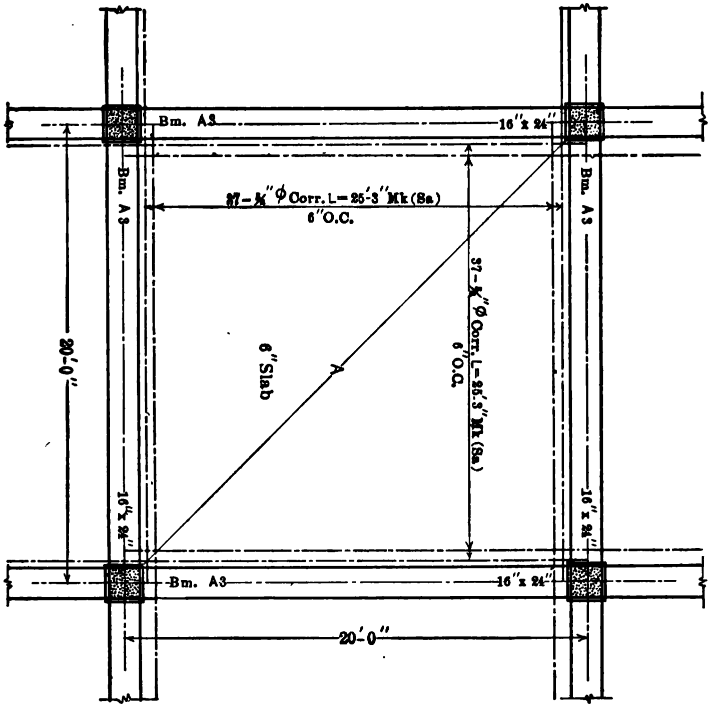


FIG. 74. TWO-WAY REINFORCEMENT IN A SOLID SLAB.

This method allows of the reduction of the slab thickness and the reinforcement in each direction carries a part of the load depending upon the spans of the panel. It necessitates the use of beams on all four sides of the panels.

(*a*) A section of a slab using **Berger's** Pressed Steel **Floor-Cores,** manufactured by the Berger Manufacturing Company.

(*b*) A similar slab using the **Gypsum Floor-Core,** manufactured by the U. S. Gypsum Company, and

(*c*) A section of a slab using **GF Steel Tile,** manufactured by the General Fireproofing Company.

Both the tile-joist and floor-core systems necessitate subsequent plastering for an ordinary well-finished surface. For light buildings, such as for stores and offices, they are very economical.

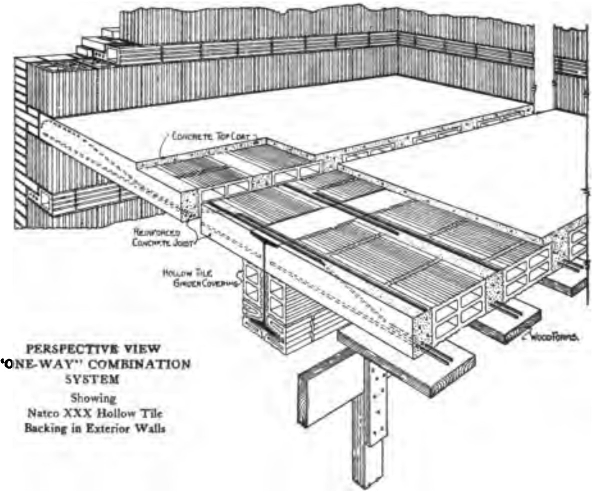

CONCRETE TOP COAT
REINFORCED CONCRETE JOIST
HOLLOW TILE GIRDER COVERING
2" WOOD FORMS
PERSPECTIVE VIEW
"ONE-WAY" COMBINATION SYSTEM
Showing
Natco XXX Hollow Tile
Backing in Exterior Walls

FIG. 75. ONE–WAY TILE JOIST SLAB.

This type of slab, in connection with the slab shown in Fig. 76, reduces the dead load of the construction materially. The tiles are placed about 4 inches or 5 inches apart, the concrete in the channels between the rows of tile serving as joists, and carrying the reinforcement.

Prob. 69*a*. If the total load carried by a slab were 240 pounds per square foot, how much of this would the reinforcement in each direction of a two-way solid slab carry? (Square Panel.)

Prob. 69*b*. A concrete tile-joist slab of 4-inch tile plus 2-inch concrete measures 16 × 20 feet face to face of carrying beams, the beams spanning the 20-foot dimension. Lay out this panel and indicate the tile. How many tile will be required if the joists are 4 inches wide?

Solution. The distance center to center of the joists is 12 inches plus 2 inches, including one-half of the width of two tile and one joist. The rows of tile would run in the 16-foot direction. The number of rows of tile would be 20 × 12 ÷ 14 = 17.

Each row of tile would have to stop short of the face of the beam at least 8 inches. This distance would be determined by the design of the beam. In order to get a whole number of tile into the 16-foot space and allow this minimum space at each end we would have to use 14 tile.

The number of tile, therefore, would be 17 × 14 = 238 tile.

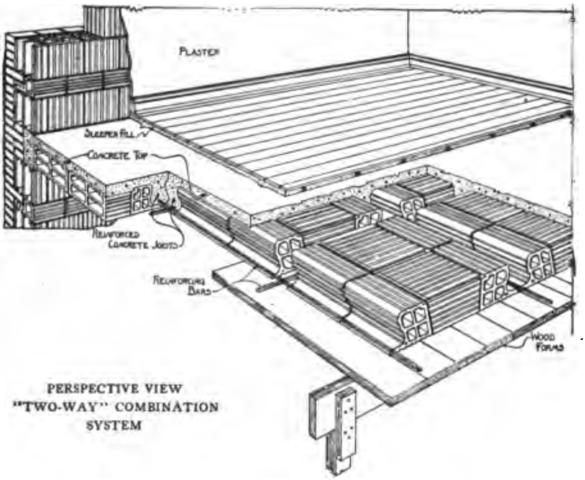


FIG. 76. TWO-WAY TILE JOIST SLAB.

This is an adaptation of the two-way construction to the tile-joist slab construction as the two-way solid is of the one-way solid slab. It combines the advantages of light dead weight and the thinner slab.

Prob. 69*c*. How many cubic feet of concrete would there be in the panel given in Problem 69*b*?

Prob. 69*d*. What is the weight of the concrete per square foot of slab in Problem 69*c*?

Prob. 69*e*. If a 4″ × 12″ × 12″ tile weighs 18 pounds, what is the weight of tile per square foot of slab in Problem 69*b*?

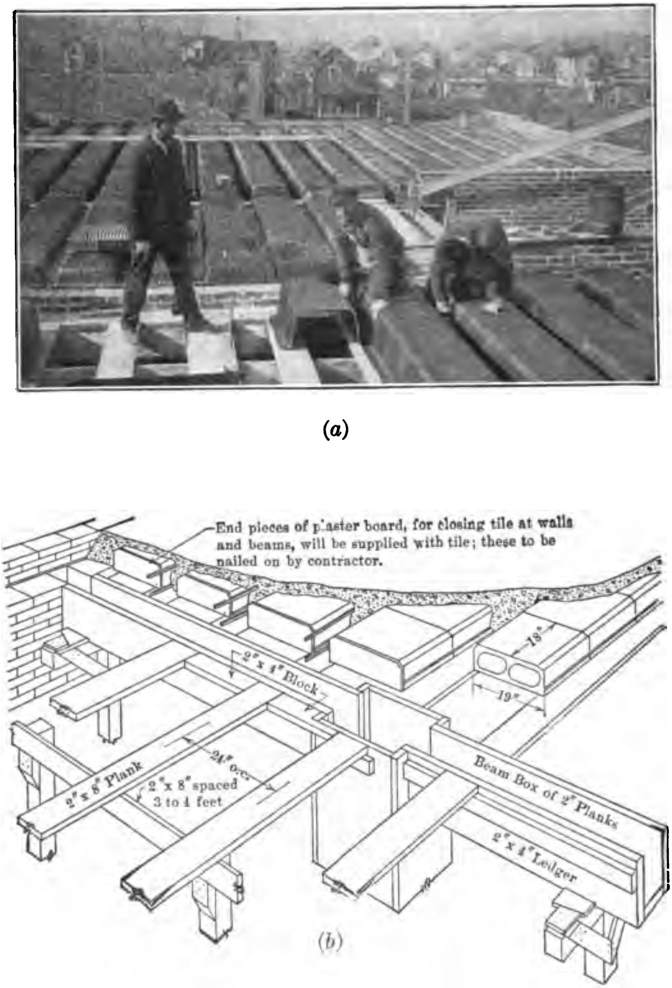
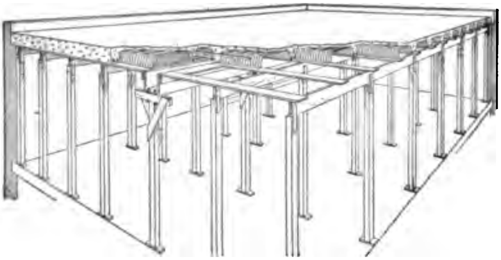

(a)
End pieces of plaster board, for closing tile at walls and beams, will be supplied with tile; these to be nailed on by contractor.
18"
19"
2" x 4" Block
24" o.c.
2" x 8" Plank
2" x 8" spaced 3 to 4 feet
Beam Box of 2" Planks
2" x 4" Ledger
(b)

FIG. 77. FLOOR-CORE CONSTRUCTION.

(*a*) *Section of Berger Floor-Core.* This type of construction has the increased advantage of lightening the dead weight to a greater degree than the tile-joist slab, and the cores may be stripped with the forms and used again.



Showing Economy of Forms and Lightness of Construction with GF Steel Tile

(c)

(b) *Gypsum Floor-Core Construction.* This is similar to the other two in principle, but it embodies a masonry material to which plaster can be easily applied, and concrete joists.

(c) *Section of GF Steel Tile.* Each of these systems has its distinct advantage, and the student should investigate the manufacturers' catalogues.

Prob. 69*f*. If a two-way, 6 + 2, tile-joist slab, with 4-inch joists, is 16 × 16 feet face to face of beams, determine:

(*a*) Weight of concrete per square foot.
(*b*) Weight of tile per square foot.
(*c*) Total dead weight of construction per square foot.

Prob. 69*g*. Make a table for the following tile-joist slabs, indicating the dead load per square foot.

Slab, 4-inch joists	One-way	Two-way
4 + 2		
5 + 2		
6 + 2		
7 + 2		
8 + 2		
10 + 2		

Prob. 69*h*. Determine the weight per square foot of a 6 + 2 one-way slab using Berger's floor-cores, GF steel tile, and the gypsum floor-core? (Use catalogues.)

70. Typical Slab and Beam Details. The typical slab details for the building we are studying would be as shown on Plate VI of the plans, and as more clearly shown in Fig. 78. The length of each rod and its shape are related. The **angle of the bend** for slabs is **30°**, as shown, and its **center** comes **at** the **point of inflection. Half** of the bars in each slab panel are bent each way, as illustrated in Fig. 79. The detail of one of the bars is shown in Fig. 80. To determine the length of this rod we will add the dimensions: **6 inches; 3 feet; 7 inches; 11 feet, 9 inches; 8 inches** for the hook, and **1 inch** for the loss in the bend, making a total of **16 feet, 7 inches.**

(*Perform Jobs No. 84, 85 and 86, Vol. II.*)

The beam details are drawn up in a similar manner. Fig. 81 shows the elevation of one of the beams in the roof frame of this building and is a reproduction of the detail of **Beam 4,** shown on Plate VI. Note that in addition to the elevation of the beam, a section is also drawn showing the disposition of the steel in that direction. The bending of the steel in

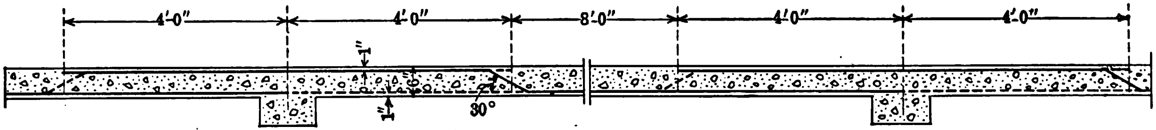


FIG. 78. DETAIL OF THE SLAB OF THIS BUILDING FROM PLATE VI.

This is one method employed by engineers to indicate the steel for continuous slabs. Some engineers object to the use of dash lines and indicate each of the rods free, thus throwing them out of place on the detail, but making the detail much clearer to the foreman.

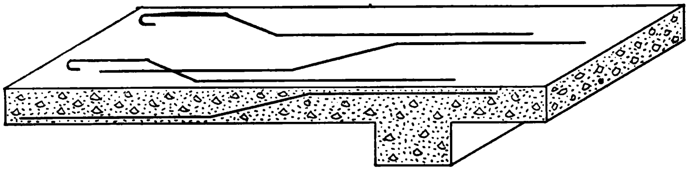


FIG. 79. BENT BARS IN POSITION IN THE SLAB.

This figure shows the alternate positions of the bends in slab bars. One-half of the positive steel in each of two adjacent panels is bent up to furnish the proper amount of negative steel over the supports.

beams is at **45°** with the horizontal and the center of each bend lines up with the point of inflection, as in slabs. By a reference to Fig. 63 it will be noted that **end spans** have their **points of inflection** at about the **fifth** or **sixth** points, while **intermediate spans** have them at their **fourth points.** In a manner similar to that shown for slabs, the lengths of the rods are determined. Bearing in mind that about one half of the steel is bent and the other half straight, the student will profit by working out some of the rod lengths in the Beam Schedule on Plate VI. The reason for bending only one-half of the steel is found in the fact that as much steel is needed **over the supports** (columns in this case) as is required in the section of the beam with positive bending. Turning up **one-half** of the steel from each of two adjacent beams gives us this amount. This method also carries some

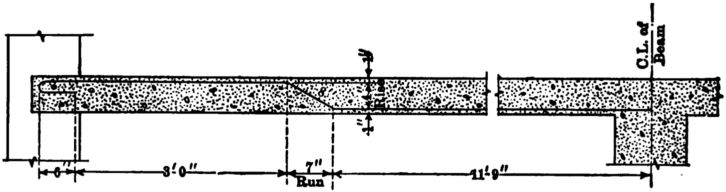


FIG. 80. SLAB BAR BENDING DETAIL.

Here the relation of the bent bar to the slab is shown. The bending schedule of the bars is worked up in a similar manner and each bar with a bend is marked. The schedule gives the number of bars, the size, the length, and the detail of the bend.

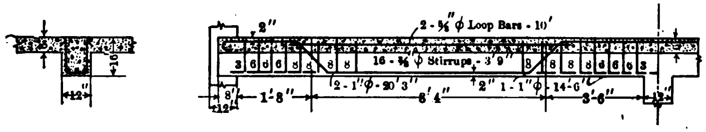


FIG. 81. ELEVATION AND SECTION OF BEAM 4, PLATE VII.

This is an enlargement on the detail given on Plate VII. Note the method of detailing the tension and shear steel (stirrups), and the use that is made of the loop bar for making the steel up into a frame, or cage.

of the **positive steel,** so-called, clear to the end of the beam, a condition which is called for in nearly all building codes.

To determine the loss in the bend the following steps are taken:

$$\text{Determine } \textbf{rise} \text{ of bend}\left\{\begin{array}{l}\text{Slab thickness minus 2 inches,}\\ \text{Beam depth minus 4 inches.}\end{array}\right.$$

$$\text{Determine } \textbf{run} \text{ of bend: rise times}\left\{\begin{array}{ll}1.73 & \text{for slabs,}\\ 1.0 & \text{for beams.}\end{array}\right.$$

Length of bend will then be $\sqrt{\text{rise}^2 + \text{run}^2}$, or, approximately, rise times 2 for slabs, and times 1.41 for beams.

Subtract the **run from** the **length** of the bend, and the result will be the loss in the bend.

For example: — Determine the loss in the bend for a beam 20 inches deep. (Fig. 82.)

$$\begin{aligned}\text{Rise} &= 20 - 4 = 16 \text{ inches}\\ \text{Run} &= 16 \times 1.0 = 16 \text{ inches}\\ \text{Length} &= 16 \times 1.41 = 22.6 \text{ inches}\\ \text{Loss in the bend} &= 23 - 16 = 7 \text{ inches.}\end{aligned}$$

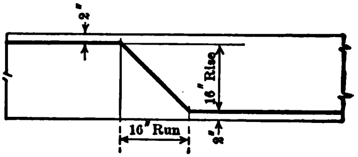


FIG. 82. DETERMINATION OF LOSS IN BEND.

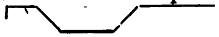
The student will profit by a careful study of the beam schedule in order to acquaint himself with a **method** of doing this work which is followed in many offices. Some engineers **detail each beam separately,** placing all of the information upon the section and elevation of the beam. This is a more thorough method and one which saves the contractor much time. As plans are not generally drawn in this fashion, it is very important for the contractor to be able to make such details from the plans directly, or from the beam schedule.

Prob. 70*a*. What is the loss in the bend of a steel rod in an 8-inch slab? 12-inch slab?

Solution.

Rise of bend $= 8 - 2 = 6$ inches
Run of bend $= 6 \times 1.73 = 10\frac{3}{8}$ inches
Length of bend $= \sqrt{6^2 + 10.38^2} = 12$ inches (approx.)
Loss in bend $= 12 - 10\frac{3}{8} = 1\frac{5}{8}$ inches.

Prob. 70*b*. Determine the loss in bend of a steel rod in a 24-inch beam? A 16-inch beam?

Prob. 70*c*. If the shape of the bend of the steel in a 36-inch beam is  what is the loss in the bend?

Prob. 70*d*. An 8-inch slab spans from a 12-inch brick wall to a beam, a distance of 16 feet in the clear (beam 16 inches wide), and the panel adjacent to the beam on its other side is 16 feet wide, c. to c. of beams. How long will the rod which bends up in the slab at the wall be? How long will the rod which bends up in the slab over the beam be? Have you allowed for a hook in the first case? If the rod is $\frac{3}{4}''\varnothing$ how much will you allow for the hook?

Prob. 70*e*. A 6-inch slab spans 20 feet from wall to wall. The walls are 12 inches thick and the slab has an 8-inch bearing on each wall. Will the alternate bars be of the same length?

71. Plant for Concreting. It is not the intention to go into the details of the plant for extensive concrete operations here and the student is advised to keep in touch with building operations in the vicinity and the discussions of **plant** in periodicals, with a view to broadening his appreciation of the elements of **time, accessibility,** and **economy** in handling concrete materials of all kinds.

The emphasis laid upon proper **pre-planning** of the plant in Chapter III, p. 37, is again brought to the attention of the student. The plant in addition must be **well balanced.** No part of the scheme (the **charging, mixing** and **handling**) should be made larger or smaller than the others, as has often been done. The size of the job, and the plant layout will be determining factors in the size of these units. At times it will be more economical to use a single large unit,

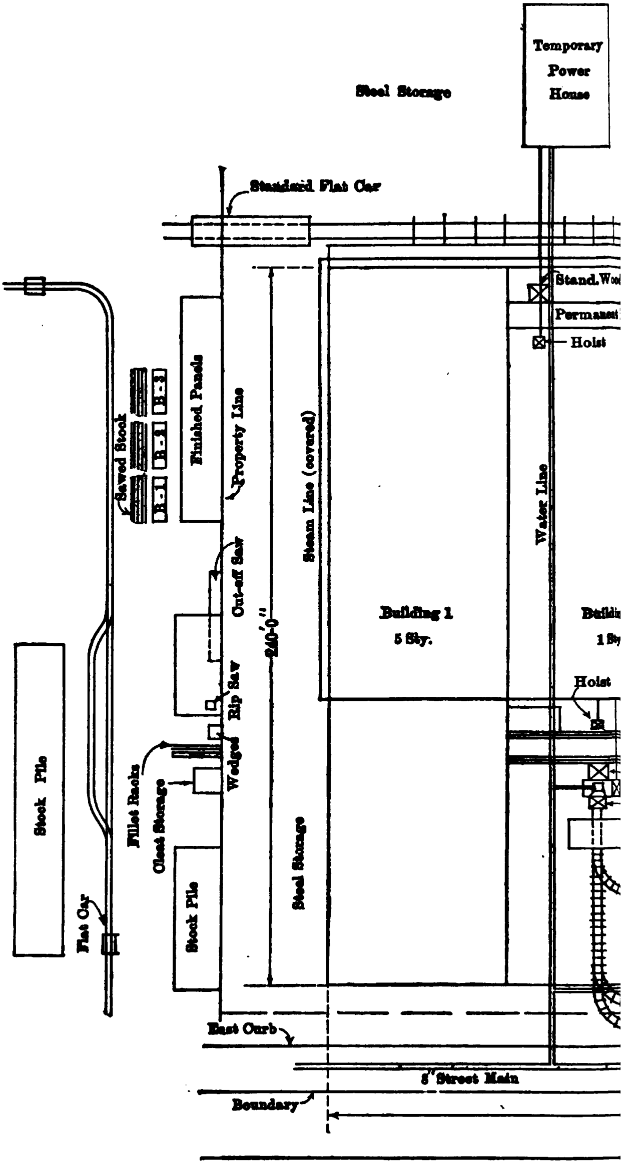
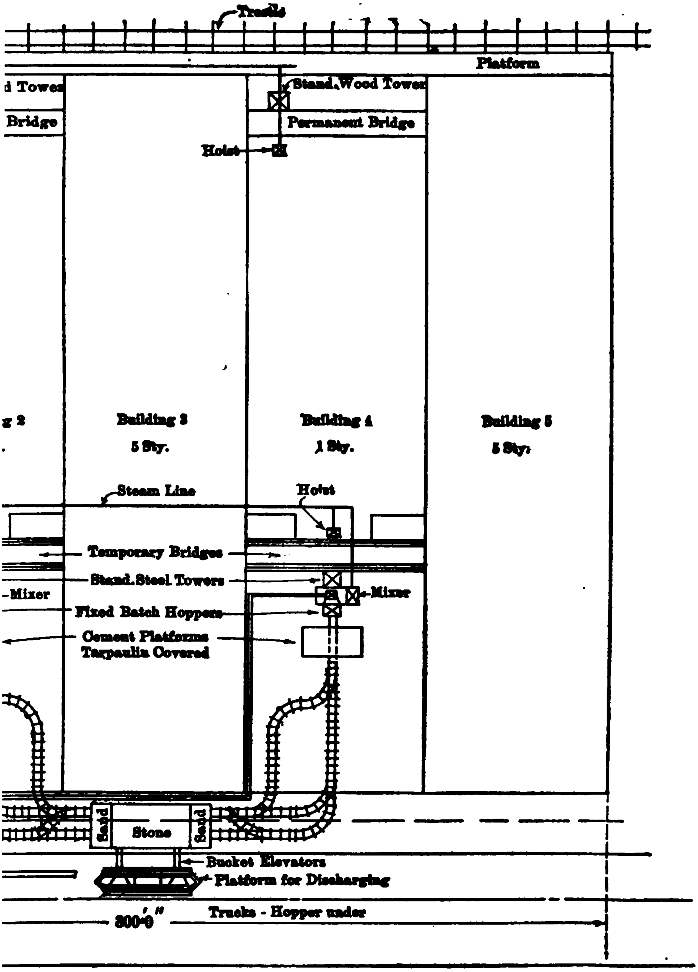


Fig. 84. Plant Used in Co
Company's Building at Ne
tion Company, Contracti



ection With the Seamless Rubber
Haven, Conn., Aberthaw Construc-
Engineers.

while at other times several smaller units, placed at **advantageous points,** are more economical.

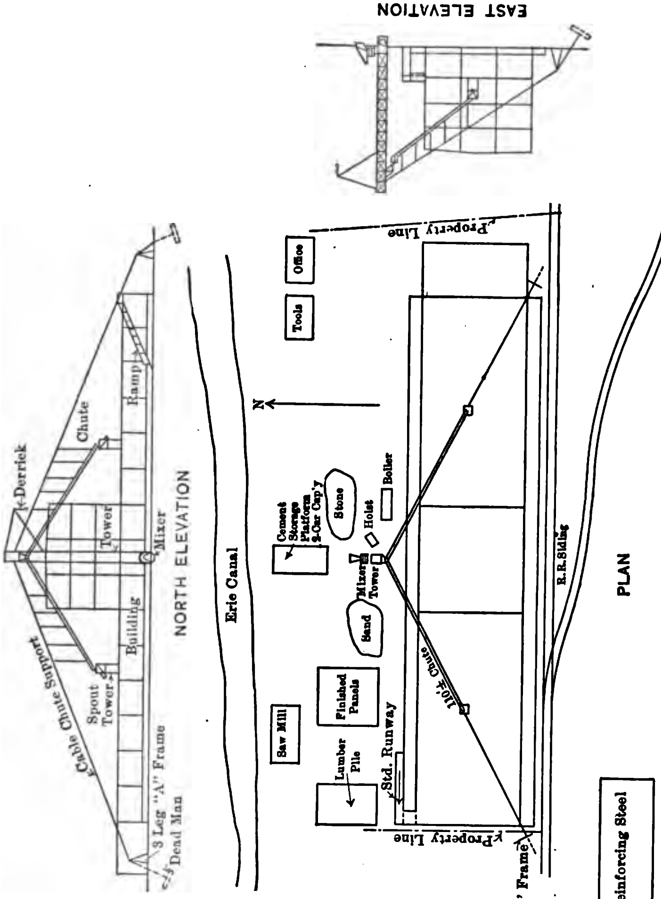


FIG. 83. PLANT USED IN CONNECTION WITH THE ERECTION OF THE GINGER ALE BUILDING OF THE BEECHNUT PACKING COMPANY AT CANAJOHARIE, N. Y., ABERTHAW CONSTRUCTION COMPANY, CONTRACTING ENGINEERS.

Figs. 83, 84 and 85 illustrate the plants used by the Aberthaw Construction Company on:

83. Beechnut Packing Company's Building at Canajoharie, N. Y.

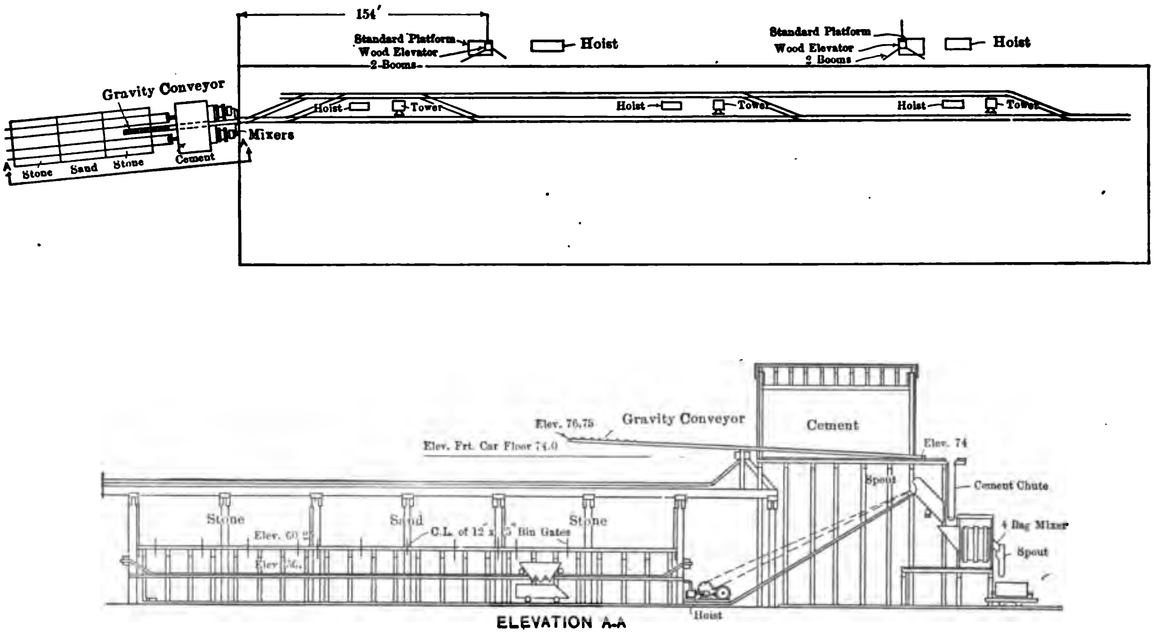


FIG. 85. MIXING PLANT USED ON THE JACKSON MILLS AT NASHUA, N. H., BY THE ABERTHAW CONSTRUCTION COMPANY.

84. Seamless Rubber Company's Building at New Haven, Conn.
85. Jackson Mills at Nashua, N. H.

In connection with these the following information is valuable:

	Yardage of concrete	Floor area	Type of delivery	Height of building
				Feet
Canajoharie, N. Y...	3,460	48,000	Chutes and Towers.....	±50
New Haven, Conn...	14,500	312,360	Towers.......	±75
Nashua, N. H.......	23,485	410,200	Elevators.....	±100

From these the student should draw conclusions as to the general nature of plants. In addition he should study the information given in Taylor and Thompson's "Concrete Costs," pp. 321 to 380, and in Hool and Johnson's "Concrete Engineer's Handbook," pp. 181 to 203. For valuable information on towers and spouting a **study of the catalogues** of the Insley Manufacturing Company, Indianapolis, Ind., and the Allied Construction Machinery Corporation, 120 Broadway, N. Y. City, should show excellent results.

(Perform Job No. 132, Vol. II.)

72. Placing Concrete in Columns. The concrete for columns is placed either by spouting, or from carts or barrows. **Runways** are led to the various parts of the floor, resting upon **horses** or **bents** for support. The columns are **cast to the bottom of the beam or slab,** as the case may be; or they are **cast to the bottom of the column capital** in flat slab construction. The important factors in the placing of concrete in columns are **continuous deposition** to completion and the proper spading to produce a dense concrete and smooth column faces. Localized placing is, of course, necessary in this case and the type of form lends itself naturally to such deposition. In order to get **well bedded reinforcement** the **spading** should be carried on continuously with the placing and the concrete should not be run to the form faster than this work can be done. Note that it is the tendency to use excessively wet concrete to lessen the labor along these lines, but **sufficient mixing,** use of **finer ballast,** and **adequate spading** is the better process.

A fine **scum** is likely to collect on the top of the concrete in a poured column where wet concrete is used and has been well churned. This should be **thoroughly removed** before any further concrete is poured.

73. Placing Concrete in Beams and Slabs. The concrete in floor systems may also be placed by spouting. In large constructions this is sometimes done, but many large buildings have been **concreted** by carting the materials to the various parts of the floor system on runways properly prepared for such work which can be stripped back as the work nears the tower. Fig. 86 is a picture of such a runway system for a concrete building. Note the small horses used to span the reinforcement and to keep the planking high enough to clear it. It is generally conceded that concrete which is cast continuously to completion always results in a better appearing job and, because of the lack of **cleavage planes,** in a more dense concrete, which wears well. If the work must be stopped, the stoppage or cleavage plane should occur at **right angles** with the **tension reinforcement,** as a stoppage plane is a point of weakness in shear (See Art. 27, "Strength of Materials," by Mansfield Merriman, Sixth Edition). The shear is the **greatest at the support** in simple beams supported at both ends and is **zero at the center** of such members. It is therefore advisable to have these planes of weakness in shear at the point where the shear, which the reinforced concrete is called upon to bear, is the least. Fig. 87 shows a section of a slab and beam in the roof construction of this building, with the stoppage boards in place. It is best to use these boards to prevent **excessive lateral flowing** of the concrete at these points. We have covered, generally, the following precautions in concrete placing:

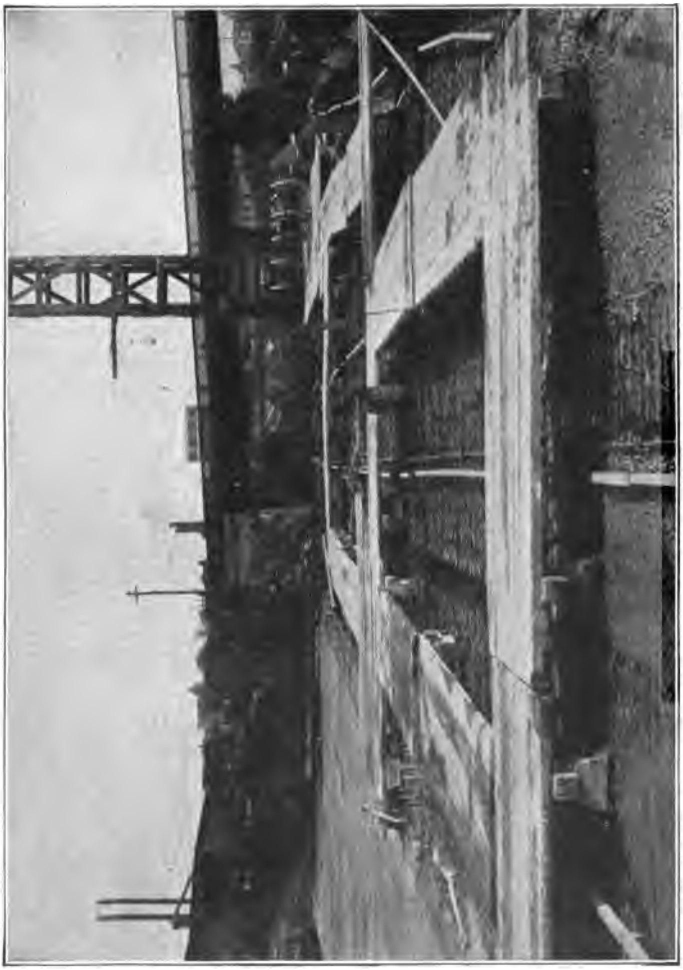


FIG. 86. RUNWAYS FOR SLAB CASTING.

This picture, furnished through the courtesy of the American Steel and Wire Company, shows the small horses that span the reinforcement upon which the plank runways are placed. These runways are removed as the work progresses.

1. **Continuous and even placing.**
2. Concrete to be placed in **even horizontal layers** of not too

great a thickness, in order to prevent lateral flowing and the separation of the parts of the mix.

3. The plant shall be such as to **avoid segregation of** the **constituent parts** of the mix.
4. **Deposition to completion** when possible.
5. Proper precaution shall be taken to **bond new and old** concrete.
6. The **drop** of the concrete shall **not** be **too great,** as air is unnecessarily entrained in too great a fall.
7. Concrete shall be **spaded, puddled** and **tamped** to bring the mortar in contact with all form faces and reinforcement.

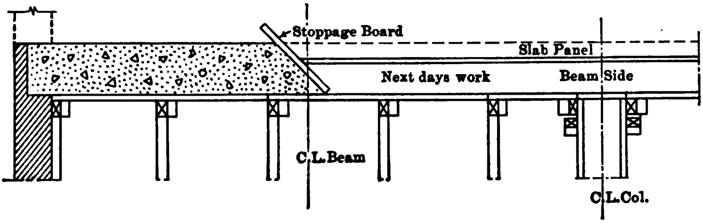


FIG. 87. STOP BOARDS.

When it is necessary to stop work in the middle of a floor, it is advisable to place these stop boards at the points of minimum shear in beams and slabs.

The student will gain, by **experience and observation,** many valuable suggestions along these lines.

Prob. 73*a*. Write a discussion on this building covering, the successive portions to be cast, enumerating the construction joints clearly, if the plant has a capacity of 100 cubic yards of concrete daily. How many days, barring breakdowns, will be required for actual concreting?

74. Form Removal. The following quotation from the Final Report of the Joint Committee on Concrete and Reinforced Concrete adopted on July 1, 1916, on forms is based on form removal:

> "It is vitally important to allow sufficient time for the proper hardening of concrete, which should be deter-

mined by careful inspection before the forms are removed.

Many conditions affect the hardening of concrete, and the proper time for the removal of forms should be determined by some competent and responsible person.

It may be stated in a general way that forms should remain in place for reinforced concrete longer than is required for plain concrete and longer for horizontal than is required for vertical members.

In general it may be concluded that concrete has hardened sufficiently when it has a distinctive ring under the blow of a hammer, but this test is not reliable, if there is a possibility that the concrete is frozen."

Next in importance to the erection of forms is the **removal** of them. Great care and judgment should be exercised in this respect. Many **failures** have resulted from **too early a removal** of forms. Likewise, much money value has been sacrificed in leaving forms in place too long. It is far better to err in the second direction, however, than in the first.

The factors entering into this phase of construction are based upon four important considerations. **Weather** has a marked effect upon the setting of cement. **Warm, dry weather hastens** the set of the cement, while **cold, damp weather retards** the set. The **position of the form** many times **determines** its time of **removal.** Those forms which were used for making **horizontal members** must **remain in place longer** than column or wall forms. It is, therefore, important that the forms be so assembled that the horizontal parts can be allowed to remain after the vertical parts are removed. (See Table XVIII.) The **quality of the cement** affects the time of removal to a marked extent. The more rapid setting a cement is, the sooner the forms can be removed. The two types of loads coming upon the structure are known as the **dead** and **live** loads. The **dead load** is that portion of the load the structure **continually** carries, inasmuch as it is the weight of the structure itself. The **live load** is the portion of the load which is **super-imposed** in the way of people, machinery, equipment, and so forth. The **greater** the proportion of the total load contained in the **dead load,** the **longer** the **forms** must **remain.** Therefore, one finds that the forms for roofs, long span beams, and top story columns are left in place longer than those for other floors or portions. Table XVIII, which follows, has been recommended by the Illinois Department of Factory Investigation, and is reprinted here from Hool & Johnson's "Concrete Engineer's Handbook."

TABLE XVIII

FORM REMOVAL

Temperature	Above 60° F.	50°–60° F.	40°–50° F.
Column sides......	Within 3 days	5 days	10 days or more
Beam sides........	Within 4 days	6 days	10 days or more
Beam bottoms, less than 14-foot span	Within 14 days	18 days	14 days or more
Floor panels, less than 6-foot span	Within 4 days	8 days	14 days or more

For beam bottoms and floor panels add one day for each additional foot of span.

Prob. 74*a*. How long would you allow the roof panel forms to remain in place if the work was done in the northern states during July? During October?

Prob. 74*b*. . How soon would you remove the beam bottoms on this building if the work was done during December in the Southern States?

75. Patching Concrete. Hardly any job of concreting is so well done as to avoid subsequent **patching.** Improper spading, leaky forms, and the improper alignment of concrete faces due to bulged forms necessitate the repair of irregularities.

The first two causes are responsible for porous concrete, sand pockets, and the like. Where these occur, it is advisable **to trim back** the **spots** with a chisel and to **plaster** them up **with a cement mortar.** After the defect is trimmed back it should be cleared of all loose particles and dust, and then **painted** with a **thin cement grout,** before the plastering is begun. If the patch is large and on a vertical surface, the work will have to be built up in several operations to avoid the sagging of the wet mortar. It is always safe practice to **cut** a few **reëntrant pockets** in the hole so as to give the mortar a mechanical as well as a natural bond.

Forms which lack the rigidity necessary to hold true to alignment during concreting necessitate the trimming of the surfaces affected by the **bulging.** This is done with a **bush-hammer while** the concrete is still quite **green,** and the trimming should be carried about ½ inch back of the finished face. The surface is then **grouted** and **plastered** to line with a cement mortar.

Sometimes the irregularities in the surfaces of the concrete are slight. It is then possible to patch the small holes with a neat cement mortar and to follow this up with **rubbing** on the next day. The rubbing is done with a **carborundum brick** and **cement grout.** This is usually necessary where the concrete faces are exposed parts of the building, and where a rubbed finish is specified. **If** the finish is specified **"bush-hammered,"** this operation can be **carried on,** after the patching has been done, **with** the **rest of** the **building finish.**

(*Perform Job No.* 70, *Vol. II.*)

76. Types of Skylights. The type of skylight shown on the plans of this building is undoubtedly the most economical for concrete construction. The best **uniform lighting** for buildings such as this would be obtained from the **saw-tooth** skylight as illustrated in Fig. 88. Another type of skylight used considerably is a combination of these two and is illustrated in Fig. 89. The last two are expensive in concrete, due to the special forms required, and the careful **flashing** against leakage which is necessary. They allow more direct ventilation, because the sash may be movable. They also exclude direct sun rays, which is a distinct advantage in lighting and comfort.

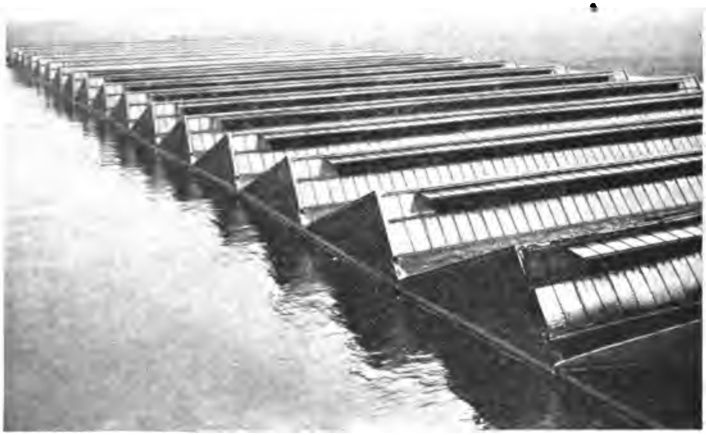


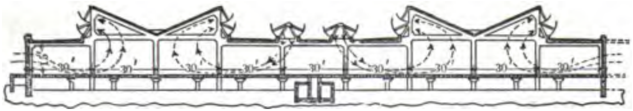
Fig. 88. Saw-Tooth Skylight.

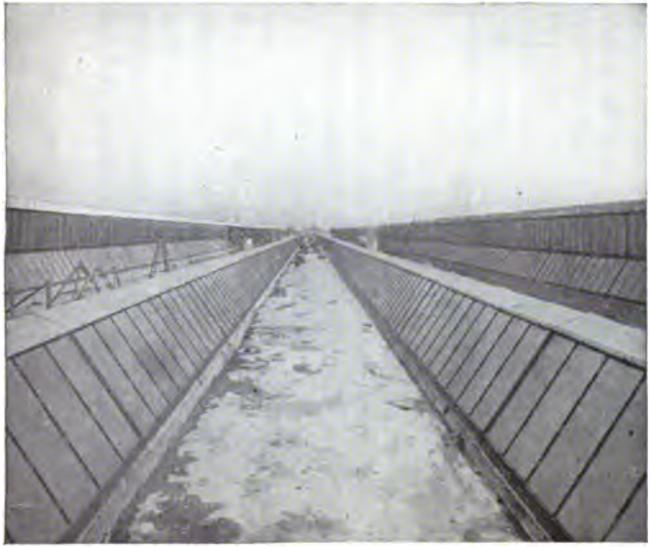
This is a typical installation of such a skylight on the General Electric Company's works at Erie, Pa. This work was done by the David Lupton's Sons Company, and the picture is furnished through their courtesy.

Prob. 76*a*. Draw a detail to 1½-inch scale of the following types of flashing for the skylight of this building:

Metal cap and base flashing.
Johns-Manville cap and base flashing.
The Barrett Reggle strip cap flashing.

(Consult manufacturers' catalogues.)





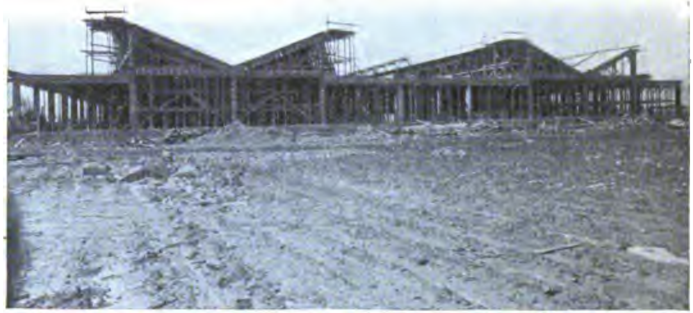


FIG. 89. POND-A-FRAME SKYLIGHT.

This is an installation in the Domestic Engineering Company's plant near Dayton, Ohio. The section of the building, the view between the two Pond-A-Frames, and the elevation of the concrete skeleton of the building during erection are shown. This skylight construction is a product of the David Lupton's Sons Company.

77. Skylight Curb-Walls and Anchors. In most cases of this kind the walls forming the support for the skylight are reinforced as beams. This is the case in this building and the student should study this detail. The tops of the curb walls are provided with **anchors** by means of which the **skylight plate** (Fig. 90) is fastened. This is usually **wood** as shown, but it is often a **bent steel plate** as illustrated in Fig. 91. To this plate the unit skylight is fastened. The frame in such cases as this would come to the job built up to detail, and it is the contractor's duty to check the drawings submitted by the skylight contractor, before he is allowed to go ahead with their manufacture. The exact construction of these frames varies with different manufacturers and the student is referred to the catalogues of The G. Drouvé Company, Van Noorden & Co., Lupton Son's Company and to Sweet's Index for additional valuable information as to their **details.**

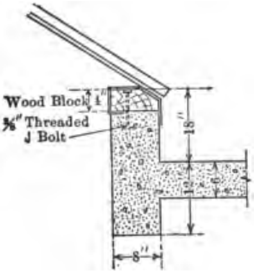


Fig. 90. Wood Curb Wall Plate.

In order to fasten the ordinary skylight to the skylight curb-walls, a plate of either wood or steel must be anchored into the concrete. This affords a fastening for the skylight frame.

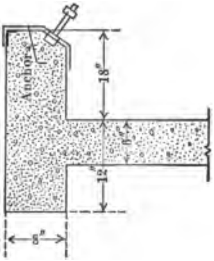


Fig. 91. Steel Curb Wall Plate.

(Perform Job No. 87, Vol. II.)

78. Glass for Skylights. The **fire hazards** incident to roof construction, as well as the danger from falling glass due to breakage, have resulted in the uniform specification of **wired glass for skylights.** The glass ordinarily used is either **rough**

or **ribbed wire** glass about ¼ **inch** thick, especially if the **glass** is nearly horizontal in position. Further points relative to glass and glazing will be considered in connection with the sash of our building, in Chapter XI.

79. Expansion and Contraction of Concrete. Good results in concrete construction depend upon provision for the movement of concrete after it has been placed. Concrete **shrinks** when setting **in air** and **expands** when setting **in water.** Reinforcement is sometimes necessary to prevent cracks due to shrinkage. Fillets and shapes of sections of concrete structures must take such shrinkage. For instance, where a thin slab joins a large beam the former may tear away.

The amount of shrinkage depends upon the **temperature** at which the concrete was poured, the **amount of water** used, the **kind of cement,** the **amount of the cement,** and the **curing.** The amount of shrinkage may be expected to be 0.02 to 0.05 per cent when setting in air, and when it sets in water it may expand one-half of this amount (0.05 per cent of length is 0.6 inch in 100 feet.) The change goes on for over two months. The consequence of this shrinkage is that the slab will pull itself apart if held at the ends, unless steel is introduced to take up the stresses and to hold it together.

Concrete also **expands when heated** and **contracts when cooled.** The amount of this movement increases with the richness of the mix. The coefficient is nearly that of steel, or 0.0000065 per degree, Fahrenheit, or nearly 0.8 inch per 100 ft. per 100 degrees. This produces open cracks in pavements and walks, and may crack a restrained slab. Similarly the **expansion** will **buckle** curbs and walks, unless expansion joints are provided.

Long stretches of wall and slabs may be built without expansion joints, provided enough steel is introduced to hold the concrete together. The **effect of this steel** is not to stop the movement but **to distribute the total change in length,** producing a large number of very small cracks that do not seem to damage the structure. For this purpose 0.04 per cent of steel will ordinarily suffice. The temperature steel for the roof of this building is for this purpose and is usually

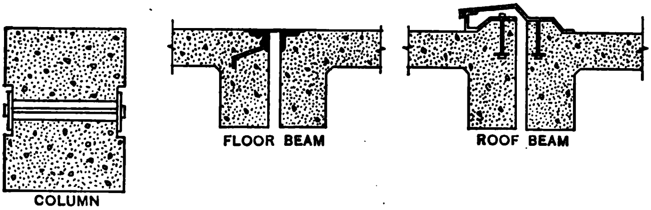


FIG. 92. EXPANSION JOINTS IN CONCRETE CONSTRUCTION.

Where concrete structures are long, and there is a possibility of excessive expansion, the buildings are provided with joints which extend the entire height of the building. The columns and floor and roof beams are so divided that they can act independently.

$\frac{3}{8}''$Ø rods spaced from 18 to 24 inches on centers across the main reinforcement.

Concrete acts like wood in expanding when it is wet and contracting when it dries out. These changes due to moisture may reverse the changes due to temperature. When contraction joints are placed in walls, they should be spaced about 30 feet apart and waterproofed.* They will then be where cracks may be expected in a structure without joints. The good appearance of the structure is in this way preserved. Cracks due to shrinkage when hardening, may be kept to a minimum by proper **curing** (keeping the concrete wet). There is less cracking when the concrete is laid in cold weather than when it is laid in warm weather. The cracks produced by contraction may be clear through the concrete, or they may be slight **crazes** on the surface.

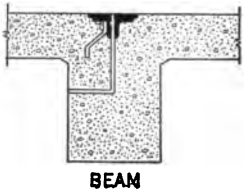


FIG. 93. LAPPED EXPANSION JOINT.

When it is advisable to place an expansion joint in a slab only, this is accomplished by lapping the slab upon a beam.

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*These joints should not be farther apart than indicated by the daily capacity of the concrete mixer.

When expansion joints are used, they should be arranged **to separate the building completely from the bottom to the top.** All parts should be separate, columns, beams and all. Fig. 92 shows the details of the column, floor and roof joints for a building. Very often, expansion joints are lapped as shown in Fig. 93, to avoid the column joint. This is in violation of the caution just given but there are times when such a joint is used.

(Perform Job No. 88, Vol. II.)

Prob. 79*a*. The coefficient of expansion of steel is 0.0000065 per degree Fahrenheit. How much longer would a piece of steel rod which is 20 feet at 20° F. be at 90° F.?

Solution. Each inch will increase 0.0000065 inch per degree. 20 feet = 240 inches. For each degree rise in temperature the rod will lengthen $240 \times 0.0000065 = 0.00156$ inch. For an increase of $90° - 20° = 70°$, the increase in length would be $70 \times 0.00156 = 0.11$ inch.

Prob. 79*b*. Disregarding shrinkage after casting, and assuming that ½ inch of expansion is the maximum allowable, how often would you introduce expansion joints into a slab? (Extremes of temperature −20° F. and 90° F. Express your answer in feet.)

Prob. 79*c*. If a slab 300 feet long is cast so that it sets in air, how many ½-inch joints would you advise, taking into account a shrinkage of 0.03 per cent and temperature limits of 0° F. and 100° F.?

Prob. 79*d*. If ⅜″Ø rods are placed 24 inches o.c. in a 12-inch wall, what percentage of temperature reinforcement will this be? What steel would 0.04 per cent give you?

Prob. 79*e*. In a mass concrete wall, where the temperature varies from −10° F. to 90° F., and which contracts 0.03 per cent, the contraction joints were placed 25 feet apart. How far would the concrete faces of the joint separate due to contraction? Would this be enough to allow for expansion? How would you remedy it, if not large enough?

80. Concrete Stairs. Concrete stairs are essentially **bent slabs** formed to the riser and tread. In our building the stairs to the boiler room are cast after the foundations are in. Fig. 94 shows the plan and details enlarged from the general plans with sections of the wall pocket and paving joint. Note the construction of the pocket and the bending and arrangement of the steel. The flight from the boiler room floor to the wall pocket is a single span and the upper flight spans from the paving of the first floor to the lower flight. This method of stair support is in very common use and the student will obtain valuable experience from the detailing of some concrete stairs in a building already erected by inspecting the construction.

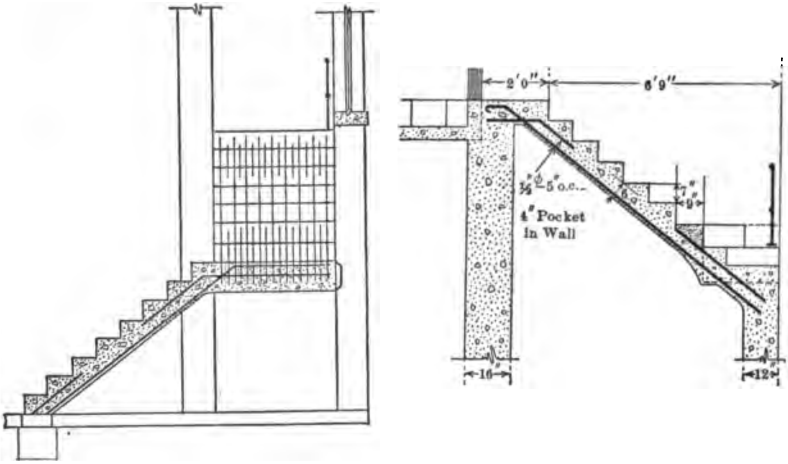


FIG. 94. STAIR REINFORCEMENT DETAILS.

The stairs in this building are bonded into the North wall by the means of pockets. Note the use of positive and negative steel in the slabs, and the fact that the lower flight spans from the boiler room floor to the wall, while the upper flight spans from the lower flight to the first floor paving over the basement retaining wall.

The forming of treads and risers can be done in many ways, and the form details shown in Fig. 95 are a suggestion for this building.

(*Perform Job No. 56, Vol. II.*)

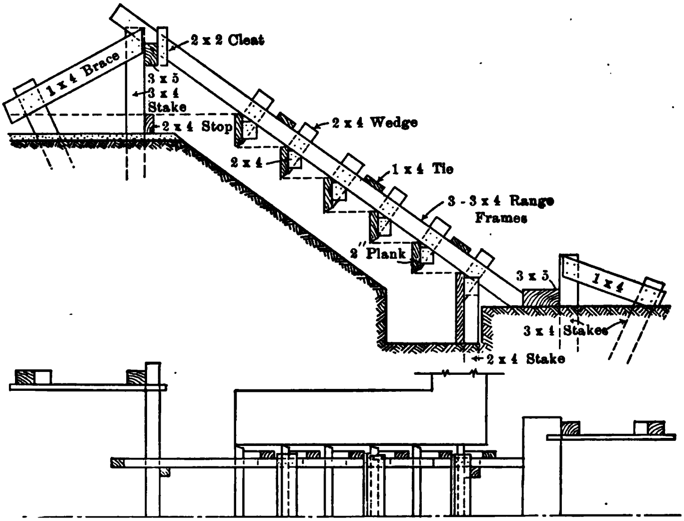


FIG. 95. TREAD AND RISER FORMS.

The forming of treads and risers has often been questioned. Here we have a simple and effective method of accomplishing this. Note the method of bracing.

Prob. 80*a*. Make details of the rods which are used in the reinforcement of the concrete stairs, showing all rises, runs and lengths.

81. Concreting in Hot and Cold Weather. Heat hastens the hardening of concrete, and cold delays it. In cold weather the water and aggregates are heated to promote hardening and thus protect the green concrete from subsequent freezing. During freezing weather, concreting should cease unless the work is so well managed that the precautions mentioned below are insured.

When green concrete has actually frozen, the water is in the form of ice. Upon thawing, this water will be available for hardening, but the water freezing into ice **has expanded and forced the mortar from the stone.** Thus there is a disintegration. The pattern of the ice crystals may be seen on the surface of pebbles of frozen concrete. Continued thawing and freezing will increase the disintegration.

When green concrete has frozen, it is damaged to some extent. Whether it is damaged badly enough to require removal is a question of circumstance, such as **danger due to** possible **failure, importance of** the **mass** of weakened concrete in relation to the remainder of the work, and the like.

At temperatures from 35° to 40° F. the materials should be heated. In any case the **weather predictions should be consulted.** The need for heating the materials will depend upon the job, heavy foundations or mass concrete being self-protected, while **thin floors** need **careful treatment.**

After the concrete is placed, it must be **protected** from the cold for **48 hours** to **4 or 5 days,** depending upon the temperature. The following are some of the precautions in the the case of small jobs. For larger jobs the student is referred to "Concreting in Cold Weather," published by the Portland Cement Association.

82. Heating Materials. Water is heated to 150° F. by either

(1) Heating the water in **tanks** over a fire.
(2) Running a **steam hose** into the water barrel. (An old steam boiler, running about 25 pounds pressure is convenient for larger jobs), or
(3) **Coils of pipe** may be laid over a fire, and the water run through this coil into the barrel.

When the supply of hot water is sufficient, the flow through the coil may be diminished so that steam will be generated to keep the water in the barrel at the proper temperature.

Sand, pebbles and stone, unless they are stored indoors, are likely to contain frozen lumps, and snow and ice. Such lumps should not be used, as they are likely to prevent thorough mixing. The materials should be heated by piling them over and around **sheet-iron cylinders** in which a fire is maintained, or on a piece of sheet iron placed upon concrete blocks. The material should be raked over for uniform heating, and the fine and coarse aggregate should be kept separate. The material may be piled over steam pipes and covered with a **tarpaulin.** These pipes are closed at one end and perforated with small holes, while the other end is connected to the steam supply.

The forms should be cleared of ice and snow, or particles of frozen concrete. The concrete after it is cast should be protected and this will depend upon the class of the work. Concrete which is **massive,** such as foundations, need only be **surface protected.** The **floors** are usually protected by from **6 to 12 inches of hay or straw,** weighted down with short boards or covered with canvas. **Important work** is **housed in,** and the temperature kept up by the use of **salamanders,** that is, **stove-pots.** The simplest form is an iron pail with holes punched in the sides near the bottom for draft, and burning coke. It is important to watch the salamanders to prevent fire or too rapid drying out of the concrete.

83. Removing Forms in Freezing Weather. Accidents have frequently occurred when forms have been taken away from concrete that was laid in freezing weather. The **concrete should be tested** by applying a blow-torch to the surface and if the water is frozen and not taken up by the concrete in hardening, it will melt and show on the surface, causing the concrete to become soft.

The time that the forms should remain depends upon the weather conditions. At a temperature of 40° F. the concrete requires four times as much time to attain a given strength as at 50°, and nine times as much as at 70°. If the concrete remains wet, a still longer time is required.

Accidents due to **too early a removal of forms** usually occur in the late fall, when the roof of the building is complete, and when the cinders are poured on the roof in piles and become saturated with rain. A desire to occupy the building forces an early removal of forms, either intentionally or by some unauthorized person, and the roof **collapses,** and carries with it a part of the lower floors.

84. Proportions of Concrete for Different Classes of Construction. Inasmuch as the frame of a building includes many varieties of construction, the following table is given for the general information of the student:

(Perform Job No. 37, Vol. II.)

TABLE XIX *

CONCRETE FOR VARIOUS PURPOSES

(1) **Heavy Foundations**

1–2–4 where great strength is required.
1–3–6 for ordinary constructions under medium loads.
1–4–8 for dams, the interior portions of bridge piers and for heavy retaining walls where the weight of the structure is of more importance than high crushing strength.
The concrete should be just wet enough to flow.

(2) **Retaining Walls**

1–3–6 for gravity walls (as above).
1–2–4 for reinforced retaining walls.

(3) **Tanks**

1–1–2 to 1–1½–3 for tanks with thin walls under six inches.
1–2–4 to 1–1½–3 for tanks with thicker walls, depending upon the depth of the tank.
It is better to err on the side of excess water here than to have the mixture too dry. An easy flowing consistency is advised.

(4) **Bridges, Arches and Culverts**

1–3–6 in heavy abutments and spandrel walls.
1–2–4 in reinforced beams, arch-ribs, slabs and railings, and in thin reinforced abutments and spandrel walls.

(5) **Columns and Piles**

1–1–2 for heavily loaded columns in lower floors.
1–1½–3 for intermediate cases.
1–2–4 for upper story columns.
1–1½–3 and 1–2–3 for piles.
The concrete should be made of as dry a consistency as can be placed and still secure a good surface.

* From Prof. Withey, Univ. of Wisconsin.

(6) **Girders, Beams and Floor Slabs**

1–2–4 for floor slabs, beams and girders in ordinary buildings or bridge constructions.

1–1½–3 for extra strong beams and girders.

The concrete should be wet enough so that it will flow easily into place, avoiding excess water.

(7) **Wearing Surfaces**

1–1½ to 1–2 for sidewalk and floor tops.

1–1 for heavy wear with a mixture of granite chips varying from ⅛ to ½ inch in diameter, and a hard siliceous sand passing a ⅛-inch ring opening; or granite screenings containing less than 15 per cent of material passing a 100-mesh sieve.

1–2–3 to 1–2–4 for one-course roads under medium or light traffic.

1–1–2 wearing course for heavy traffic, with tough granite, trap rock, or a siliceous gravel for the coarse aggregate.

In general the consistency of the wearing coat should be as dry as can be successfully finished.

Prob. 84*a*. Write a specification for the concrete which you would use for the walls of a grain elevator (mix and consistency).

Prob. 84*b*. What mix and consistency of concrete would you advise for a water tank which had 12-inch walls?

Prob. 84*c*. What sort of a specification would a concrete arch bridge have which is built between banks on either side of a stream? If the abutment walls were exposed on all sides what mix would you use for them?

Prob. 84*d*. Check the specifications for this building against Table XIX. How do they compare?

85. Problems for Review.

Prob. 85*a*. By reference to manufacturers' catalogs compare the relative strengths of a 6 + 2 construction on a 20-foot span, of each of the types of floor construction which use other materials than concrete alone.

Prob. 85*b*. A 16 × 24 beam spans from a 16-inch wall to a 12 × 12 column, distant 16 feet from the inside face of the wall. The adjacent span, continuous with the beam, is 12 feet. Determine the length and weight of a ⅞-inch ⌀ Corr. bar used in this beam. Detail the bar.

Prob. 85*c*. Make a schedule of the various kinds of equipment provided for in the plants illustrated in Figs. 83, 84, and 85.

Prob. 85*d*. Make a steel schedule for the storage cellar illustrated in Fig. 207. What is the tonnage of reinforcement?

CHAPTER VIII

PRE-CAST CONCRETE STONE

86. The Industry in Pre-Cast Concrete. Parallel with the carelessness which brought to reinforced concrete an initially bad reputation is that attending the first production of concrete stone. Starting, as it did, in advance of reinforced concrete construction this carelessness has delayed its advance as compared with reinforced concrete. The lack of **trained management** of plants and the output of **cheap machines** for block manufacture were indirectly responsible for the initial failure of the industry. Workmen who were unsuccessful in other building lines were tempted by the seeming ease of this work and turned out inferior products. The early machines for moulding concrete blocks were fashioned after an imitation of **rock-faced** stone. This drew the fire of the architects who were not averse to the concrete block fundamentally, but who disliked the **poor imitation** and the proportions, usually 8 inches high by 16 inches long, of the earlier blocks. These conditions are driving incompetent manufacturers out of the industry and are attracting manufacturers who realize that the industry is capable of scientific development and that it can result in an equal measure of success in competition with natural stone, face brick, terracotta and other similar facing materials.

Prob. 86*a*. How many standard concrete blocks are required for the concrete block partition between the coal and boiler rooms?

Prob. 86*b*. A garage is 20 × 20 feet, building line to building line, and 10 feet from foundation wall to roof plate. It has two 8 × 9 foot doors, and four 3 × 5 foot windows. How many 8-inch concrete blocks are required? How would you take care of the window and door heads?

87. Standard Units and Artificial Stone. The industry can well be divided into two classes, namely, the production of **standard units** as a simple bulk proposition and the production of **artificial stone** for the facing of buildings, which may be moulded to suit architectural designs. The former of these depends for its success upon the location of a **ready market** and the amount of study the particular manufacturer puts into his plant. The latter involves the employ of many **skilled workmen** among which are modellers, pattern-makers and stone finishers.

88. Methods of Concrete Stone Manufacture. Mr. Harvey Whipple, author of "**Concrete Stone Manufacture,**" suggests three general methods of manufacture:

(1) The **Dry-tamp.**
(2) The **Pressure.**
(3) The **Wet-cast.**

The dry-tamp method, which is used more than the other two, if placed in the hands of intelligent workmen and if used in a plant where the appropriate curing schemes are employed, may result in a good product. The first concrete blocks were made by this method in wooden moulds, but are now almost always made in **hand-tamp machines,** such as illustrated in Fig. 96. The most common abuse of this method is the use of too little water. Just enough water should be used to permit the **removal** of the block from the mould **soon** after it is made.

Pressure Machines operate by hydraulic pressure or by hand levers. Some authorities have criticized these machines, arguing that the even pressure allows less free movement of the particles of the mix. If the freedom of movement is reduced to any great extent voids will undoubtedly result. It is the opinion of the authors that this is not the case in well-operated pressure machines.

The wet-cast method has probably been more abused than the other two. This may be due to the fact that many kinds of equipment and methods are used. The quantity of water can undoubtedly be higher when **sand moulds are used,** as the excess moisture is taken up by the sand. If the product is cast in **metal moulds,** an excess of water permits an excess of entrained air and causes the product to be porous. One type of metal form which is being more generally used is the **gang-mould.** These moulds may be filled directly at the mixer or they may be placed upon the floor and the concrete carted to them.

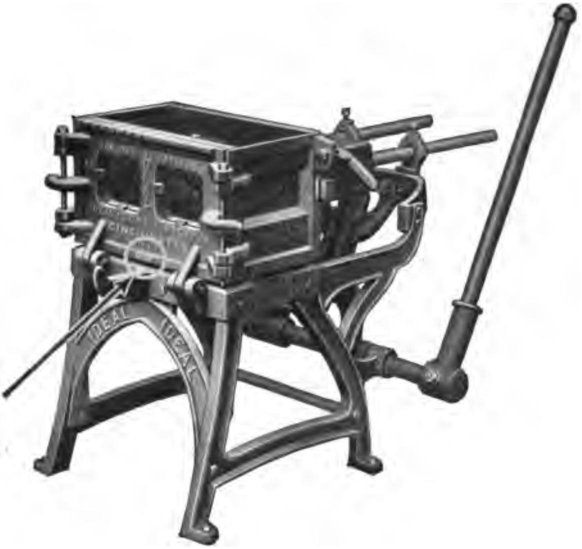


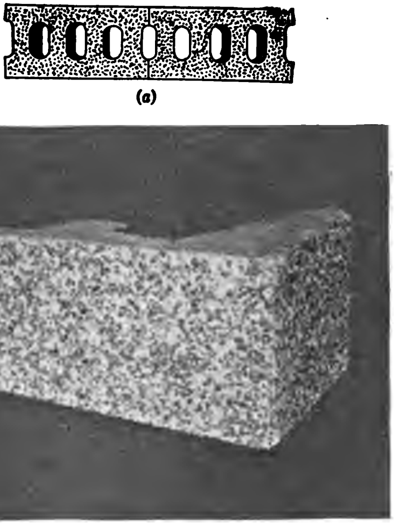
FIG. 96. THE IDEAL CONCRETE BLOCK MACHINE.
This machine is the hand-tamp machine manufactured by the Ideal Concrete Machinery Company.

89. Consistencies. In Chapter IV the question of consistency of concrete was carefully considered. Aside from the controlling features brought out there, others are added for this sort of work. In order that a concrete block industry be as economical as possible, the **moulds must be removed as quickly** as the consistency of the concrete will allow and it must be such that the concrete may be removed from the mould without damage. The greater the percentage of water, the greater will be the possibility of the **concrete sticking** to the mould. To overcome this, some manufacturers use a slightly **coarser facing** material.

The dangers arising from the use of a dry mixture will not be so great if the mixing operation covers a longer period of time and if the block is promptly removed to a curing room where the humidity and temperature do not allow any of the moisture initially in the block to evaporate.

Mixtures with high percentages of water when cast in sand moulds result in reasonably high crushing strength and density, provided sufficient time is allowed for the mixing operation.

90. Shapes of Concrete Blocks. In general, concrete blocks are of two types, those forming the entire thickness of


(a)

(b)

FIG. 97. CONCRETE BLOCKS.

(*a*) Illustrates the Brandell one-piece block which is finished with a smooth face.

(*b*) Illustrates a corner stone block of the Hydro-Stone type showing the special face obtained by using black and white granite as aggregate. This is a one-face block.

the wall and which are in **one piece,** and those which are composed of **two separate wall slabs,** together making the wall thickness. A representative sample of each of these is shown in Fig. 97. The hollow spaces save material and weight and give partially continuous air-spaces which are more or less effective in heat and moisture insulation. Some of the two-piece blocks which give almost complete continuity of air-space are shown in Fig. 98, in plan. The ties at (*a*) are made of bent steel wire and are laid in the horizontal joints of the wall. In (*b*) the ties are cast into the blocks, making this type more easily laid than (*a*). Manufacturers have developed several block shapes some of which are good and others are merely methods to fantastically overcome the known disadvantages of blocks. Fig. 99 shows three concrete blocks commonly used in some localities with success.

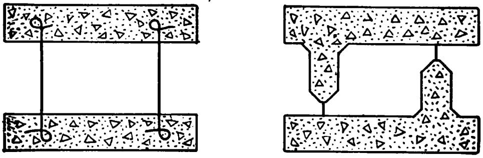
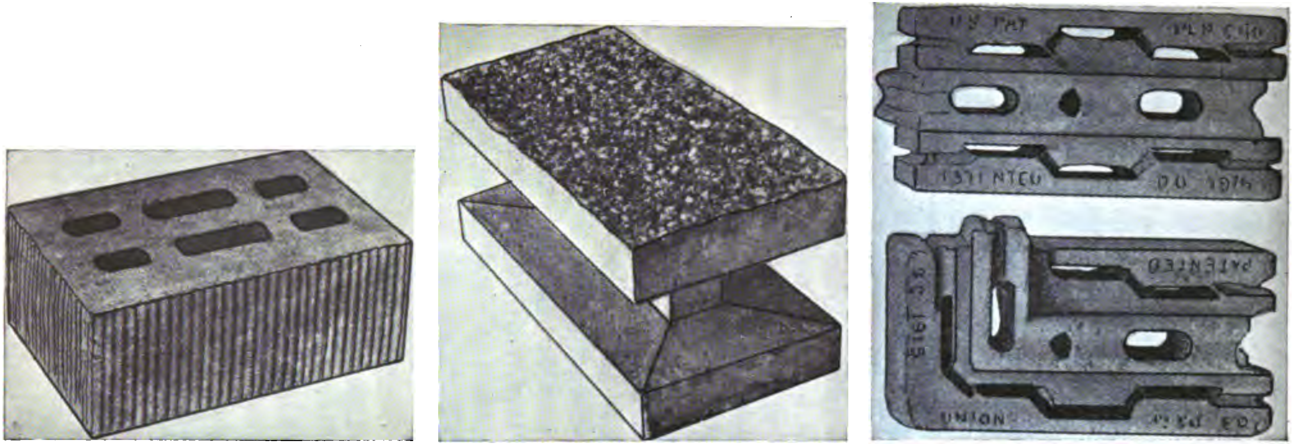

(*a*) (*b*)

FIG. 98. TWO-PIECE BLOCKS.

Two types of these blocks are here illustrated. In one (*a*) the ties are cast into the blocks, and in the other (*b*) the ties are set with the blocks as anchors.

91. Process of Block Casting. The three methods used for the casting of blocks and the consistencies advised have already been discussed. The **dry-tamp** and **wet casting processes** are probably **more used** than the pressure method. In the dry-tamp process the work is either done by hand or by hand-operated hydraulic tampers. The tamper shown in Fig. 100 is provided with a **blade-like end** and a **flat surface.** The blade end is used for tamping the concrete between the cores and the flat end for the overall tamping. The concrete is usually laid to the required depth, from (*a*) to (*b*), Fig. 101,



(a) (b) (c)

FIG. 99. CONCRETE BLOCKS.

The McIntyre block with a tooled surface is illustrated in (a); (b) is the block manufactured by the Flexo Concrete Mold Company with its special "exposed aggregate" finish; and (c) shows the peculiarly shaped Myer concrete block.

after which the cores are placed. The interspace concrete is then filled into the mould and tamped to the (*c*) line. The top surfacing is then laid and tamped. The wet-cast method uses gang-moulds almost entirely, as previously stated. These may either be mounted upon cars which lead directly to the mixer and to the curing rooms or may be mounted on the floors and cast from wheelbarrows or crane-buckets.

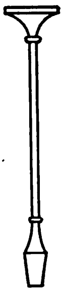


FIG. 100. HAND TAMP.

This tool is used to force the concrete into the moulds of a concrete block machine.

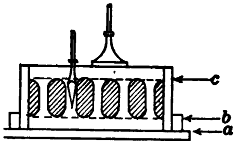


FIG. 101. CORE MOULDING.

The use of cores (cross-hatched areas) to lighten concrete blocks is common. The block is cast in three sections.

92. Pallets and Bankers. Most concrete blocks are cast upon wooden or steel plates called **pallets** corresponding to the boards used in iron moulding. If of wood, they must be cleated to prevent warping and must be sufficiently water-proof to avoid water absorption. If of iron, they must be protected against rusting, some manufacturers using paraffine oil or kerosene and axle grease to facilitate cleaning after casting. The **bankers** are usually concrete tables or horses which have sufficient weight to resist vibration, and at a height convenient for the workmen.

93. Curing. Unless concrete cast artificial units are **prevented from losing their moisture** too rapidly, they will not be sufficiently strong and will have surface cracks, or **crazes.** The process of keeping the product damp is called **curing.** It is done by **sprinkling, immersion,** and by the **use of steam.** The first two are natural methods, the products being placed upon racks in curing rooms or in tanks. The moulds are covered with damp cloths which are kept so by a fine spray (mist) from a hose. When immersion is used, the blocks are kept damp for about 24 hours and then stored in the tanks. The American Concrete Institute specifies **protection** from the sun and strong currents of **air for at least 7 days; continuous sprinkling** and maintenance of a **temperature** of not less than **50° F.**; and **storing** in the yards for about **21 days** before shipment.

Steam curing is accomplished in **curing tunnels** with a roof of such a shape that it will drain the condensed moisture to the sides of the tunnel. The temperature is usually from 100° to 130° F. The steam enters the tunnel in the form of a dense fog. This insures the moistening of all parts of the blocks. The recommendations of the American Concrete Institute on Steam Curing are:

"The products shall be removed from the moulds when the conditions permit and shall be placed in a steam curing chamber containing an atmosphere of steam saturated with water for a period of at least 48 hours. The curing chamber shall be kept at a temperature between 100° to 130° F. The product shall be removed and stored for at least 8 days."

94. Artificial Stone. The term **artificial stone** has been applied to what the American Concrete Institute calls **concrete architectural stone.** It is the industry which grew out of the manufacture of concrete blocks and is now capable of producing imitation facing stone (ashlar) comparable in most respects with the natural stones. In our building the precast sills are a sample of this sort of work.

Concrete stone which must conform to ordinary architectural detail should be **moulded.** This involves either **wood, plaster, glue** or **sand** moulds. By far the greater proportion of dimension stone is made in wooden moulds. These lend themselves very readily to belt courses, sills, lintels, cornices and the like. The process of casting a sill like the one shown in Fig. 102 would be to place a **pallet** of the correct length upon a suitable stable banker and to build the mould around this as a base, as shown in Fig. 103. The concrete is then placed by the dry-tamp method, the facing being built up to the front and sides of the mould, and the body concrete tamped into place. When the concrete is all in place up to

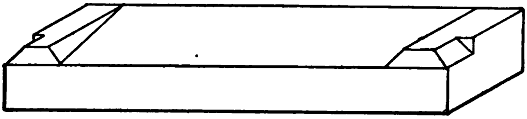


FIG. 102. ISOMETRIC OF A SILL IN THIS BUILDING.

the top, a layer of sand is placed upon it and a top pallet is rested upon this cushion. The whole mould is then turned over and when the concrete is sufficiently hard to handle, the mould is stripped leaving the sill upon the pallet right side up.

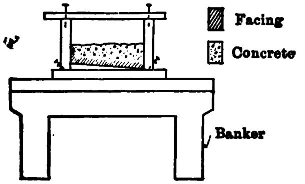


FIG. 103. CROSS SECTION OF A SILL MOULD.

The "wash" for the sill is obtained by setting the wedge-shaped strip upon the lower form board. The sides of the mould are then nailed in place. The facing mortar is backed up with the rough concrete as shown.

When the wet-cast method is used, it is customary to have a smooth slab concrete table or banker which can be **shellaced** and **oiled.** The **side pieces and inserts are** then placed in their proper positions and the whole gang cast. Great care must be exercised in both these processes to insure proper aligning of the side pieces, which can be done by properly **bracing** and **cleating** them. Sometimes steel channels are used for sides where the length of the stone calls for great stiffness.

(*Perform Job No. 110, Vol. II.*)

95. Sand Casting. This process is used extensively in eastern United States. The moulds are made by **packing sand around patterns or models.** The sand is mixed with loam or flour and is wet down to a slightly damp mixture. Some plants sprinkle **integral waterproofing powder** over the mould, after the model is drawn, to insure **protection against**

an undue absorption of the moisture which is necessary for proper lubrication from the concrete.

In casting, the drop of the concrete into the mould is broken by a board and any sharp edges that it is absolutely necessary to maintain are built up of wood in the mould, as shown in Fig. 104.

(*Perform Job No. 112, Vol. II.*)

The ordinary floor casting of concrete stone is confined to pieces which have a plane surface up to which the piece can be built. When balusters, capitals, and undercut mouldings are to be cast, the moulding is done in **flasks,** with a cope and **drag,** just as in iron foundry work. The baluster pattern is split into two parts and one half fits upon the pallet, as shown in Fig. 105. A second pallet is superimposed upon the top at (*a*) and the whole drag turned over. The cope is then fixed and the other half of the pattern is placed in position. The cope sand is then packed into the flask, and the mould is split. When the pattern is withdrawn, the concrete is **cast into a spout hole.** Great care is necessary in such work to have the concrete as fluid and as uniform as possible, and in most cases the surface of sand-moulded concrete stone is **treated.**

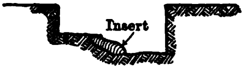


FIG. 104. SECTION THROUGH SPECIAL MOULD WITH INSERT.

In sand-casting artificial stone, wood inserts for special mouldings maintain uniformity of section.

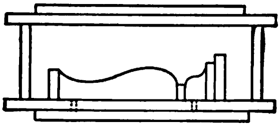


FIG. 105. BALUSTER IN A DRAG.

The casting of moulded units such as this entails the same general operations used in casting metal.

96. Surface Finishes. It is not the intention to go into the discussion of the moulding of intricate stone details, which require modelling and the making of glue and plaster moulds. The student is referred to "Concrete Stone Manufacture" by Harvey Whipple, for such a study and he is advised to visit a concrete-stone plant to see such work done, first hand.

The **body-concrete** of most architectural stones is a **1–3 mixture** of cement and a well-graded aggregate varying in fineness from that which will be retained upon a 100-mesh screen to ½ inch. (In some cases as fine as ¼-inch aggregate is used for the maximum size.) The **facing materials** are mixed in proportions of **1–2, 1–2½,** and **1–3** and vary in **character and color** with the result desired.

Artificial stone may have a:

(1) **Rubbed surface.**
(2) **Tooled surface.**
(3) **Panelled surface.**
(4) **Brushed surface.**
(5) **Sprayed surface.**

The **rubbed finish** is obtained by surfacing the block with a **No. 80 carborundum brick** after it has had a chance to harden for about 7 days. The surface is kept constantly wet and the surface film of cement is removed in this way, exposing the aggregate. Fig. 106 is a picture of such a surface and the texture and color may be varied with the constituents of the mix. **Tooling** is done after the block has hardened. The ordinary **bush-hammer,** Fig. 107, which is made up of a set of steel blades held in a clamped handle, is often used for such work, or the surface is tooled with a **toothed chisel,** Fig. 108, which is usually specified by the number of teeth per inch (**6-point, 7-point,** etc.). The chisel is driven over the surface of the block by means of a **stone-cutter's mallet,** care being taken to make all the **lines parallel** each other and the lines of the stone, and uniform. Such a surface is shown in Fig. 109.

By far the most attractive concrete finishes are those which are prearranged when the concrete is mixed and placed. The aggregates are selected for texture and color. Instead

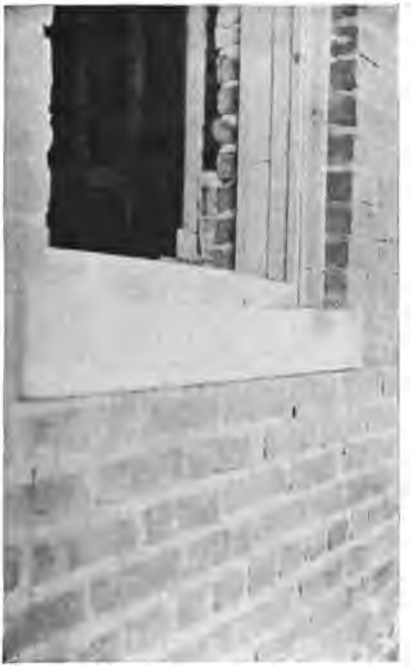


FIG. 106. RUBBED CONCRETE SURFACE.

This is one of the common finishes seen on cast-stone. The surface is obtained by rubbing the concrete with a fine carborundum brick (No. 80), using thin cement grout to keep the surface wet.

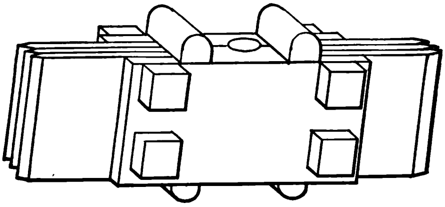


FIG. 107. PATENT BUSH HAMMER.

This hammer can be kept sharp by setting new steel blades.

of ordinary sand, **white sand, marble chips, granite screenings, mica, slag, crushed feldspar** and **garnet sand** are sometimes used. These are placed in the usual manner but when the block has hardened sufficiently to be handled the surface is brushed with a stiff bristle brush, **exposing the** colored **aggregate.** This is preferably done while the stone is in the green state. Another method of removing the surface coating is to **spray the surface** with a fine vapor spray under about 40 pounds pressure. The common method in this work is to hold the face of the block in a vertical position, allowing the water and cement to drop from the face, and thus avoiding pockets. The surface shown on the block of Hydro-Stone in Fig. 97 may have been obtained either by brushing or spraying.

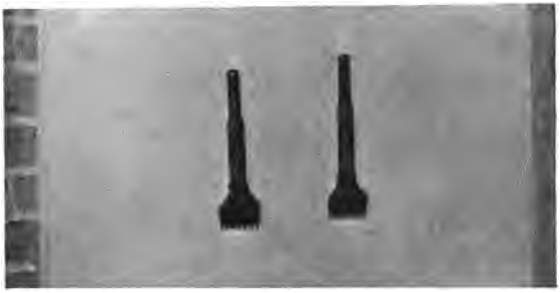


FIG. 108. TOOTHED CHISELS.

These chisels are used to produce what is called a "tooled" surface. The number of teeth per inch determine the "cut," such as 6-point, 8-point, and so forth.

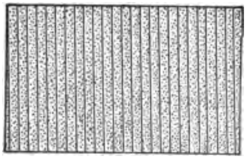


FIG. 109. TOOLED SURFACE.

97. Colors for Concrete Stone Facings. Nearly all foreign materials, such as color pigments, destroy the action of the cement in binding the constituents of the mix together. It is advisable for architectural reasons to use them, however, and Table XX gives the proportions of various colors ordinarily used.

TABLE XX *

COLOR REQUIRED FOR VARIOUS MIXES OF CONCRETE

(Based on 1–2 Mortar)

Material	Color produced by	
	½ pound per 100 pounds cement	4 pounds per 100 pounds cement
Lamp black	Light slate	Dark blue slate
Prussian blue	Light green slate	Bright blue slate
Ultra marine blue	—	Bright blue slate
Yellow ochre	Light green	Light buff
Burnt umber	Light pinkish slate	Chocolate
Venetian red	Slate, pink tinge	Dull pink
Red iron ore	Pinkish slate	Light brick red

98. Reinforced Concrete Stones. When the artificial stone is to be subjected to bending, either during erection or

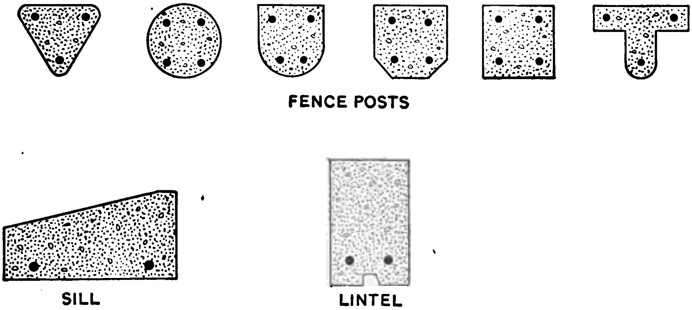


FIG. 110. LOCATION OF REINFORCEMENT IN POSTS, SILLS, AND LINTELS.

The student will note that the constructions which are allowed to bend in any direction are provided with reinforcement on all sides, while those which bend in one direction only have the steel on the tension side. (The convex side.)

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* L. C. Sabin, "Cement and Concrete," Second Edition, p. 382.

afterward, it must be **reinforced.** This is true of **long sills, concrete posts** and **lintels.** Probably no other part of this work has caused as much trouble as the **placing** of this reinforcement. It must be placed so that it will take the tension properly and Fig. 110 illustrates the position of such reinforcement for various sections of posts, a sill, and a lintel. Table XXI is taken from a Bulletin of the Portland Cement Association on **Fence Posts** and shows the materials required for posts of several dimensions.

(*Perform Job No. 111, Vol. II.*)

TABLE XXI

MATERIALS REQUIRED FOR FENCE POSTS

Dimensions			Volume of post in cubic feet	Weight of post in pounds	Amount of reinforcing metal required
Length Feet	Top Ins.	Bottom Ins.			
7	3 × 4	5 × 4	0.8	115	4-$\frac{1}{4}$″ϕ rods
8	3 × 4	5 × 4	0.9	131	
7	4 × 4	5 × 5	1.0	143	4-$\frac{5}{16}$″ϕ rods
8	4 × 4	5 × 5	1.1	163	
7	5 × 5	6 × 6	1.5	213	4$\frac{3}{8}$-″ϕ rods
8	5 × 5	6 × 6	1.7	243	

MATERIALS						
1-Cement, 3-Sand			1-Cement, 2-Sand, 3-Stone or Pebbles			
No. posts per barrel cement	For 10 posts		No. posts per barrel cement	For 10 posts		
	Sacks cement	Cubic feet sand		Sacks cement	Cubic feet sand	Cubic feet pebbles or stone
14.0	2.8	8.5	19.5	2.1	4.2	6.2
12.3	3.2	9.7	17.1	2.4	4.7	7.1
11.3	3.5	10.6	15.8	2.6	5.1	7.7
9.9	4.0	12.1	13.8	2.9	5.9	8.8
7.6	5.3	15.8	10.6	3.8	7.7	11.5
6.6	6.0	18.0	9.2	4.4	8.8	13.2

The forms or moulds for such units can be made of wood as shown in Fig. 111 or they may be metal moulds manufactured as a standard market product. The wood moulds are preferred when the number of posts cast is small, but when the number is large the metal form is better and guarantees a more uniform cross section. The **moulds** in either case **should be oiled** to facilitate the removal of the pieces, and when wood moulds are used, it is advisable to soak them in a mixture of equal parts of boiled linseed oil and kerosene to prevent moisture absorption and incident warping and swelling. Again, may it be impressed upon the student that it is extremely advisable to so construct the forms that they may be easily removed, in order that the pieces may not be injured.

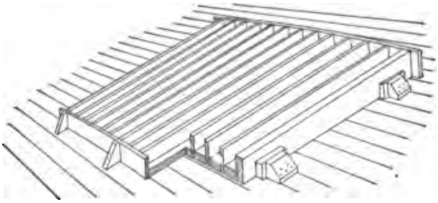

FIG. 111. WOOD MOULDS FOR FENCE POSTS.

The important consideration in this form work is the ease of stripping. This allows the repeated use of forms and tends to eliminate the possibility of broken corners.

Prob. 98*a*. What percentage of steel in cross section would the reinforcement of a 6 × 6 inch post give from Table XXI, using $5\frac{1}{2} \times 5\frac{1}{2}$ inches as the average size?

Solution.

$5.5 \times 5.5 = 30.25$ sq. in.

$4 - \frac{3}{8}Ø$ give an area of 4×0.11 square inch $= 0.44$ square inch.

$0.44 \div 30.25 \times 100$ per cent $= 1.4$ per cent.

Prob. 98*b*. Check the weights of the posts as given in Table XXI.

Prob. 98*c*. Using Fuller's Rule, check the quantities of materials needed for 10 posts as given in Table XXI.

99. Concrete Pipes. The adaptability of concrete to a great variety of shapes and sizes has made the field of **concrete pipe** quite a wide one to-day. The possibility of making a uniform section with joints which are self-centering and smooth, **preventing obstructions** in the water or sewer line, is in itself a great advantage. Concrete unit sections have been cast up to 9 feet in diameter. In general it may be said that concrete sewer or water pipe lines are **equally as good** as brick or steel and are from **20 to 50 per cent cheaper** in cost, **resisting abrasion with** as much **efficiency.**

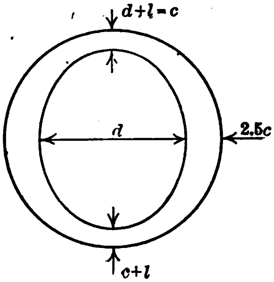

FIG. 112. RELATION OF THE PARTS OF A CONCRETE PIPE.

These are empirical relations which have been found satisfactory in practice.

The concrete proportions vary from **1–1½–3** to **1–2–4,** and the consistency is usually quite wet in order to insure density and waterproof qualities. The thickness of walls will vary with the nature of the ground and the surcharge upon them. Mr. William B. Fuller suggests for plain concrete sewers when laid in place in trench:

> 4-Inch crown thickness as a minimum, but 1 inch for each foot of diameter plus 1 inch. The invert should be 1 inch thicker than the crown, but not less than 5 inches. The haunches should be 2½ times as thick as the crown but not less than 6 inches. See Fig. 112.

The strength of concrete pipe is best illustrated by Fig. 113. This is reinforced pipe and for ordinary cases will have **longi-**

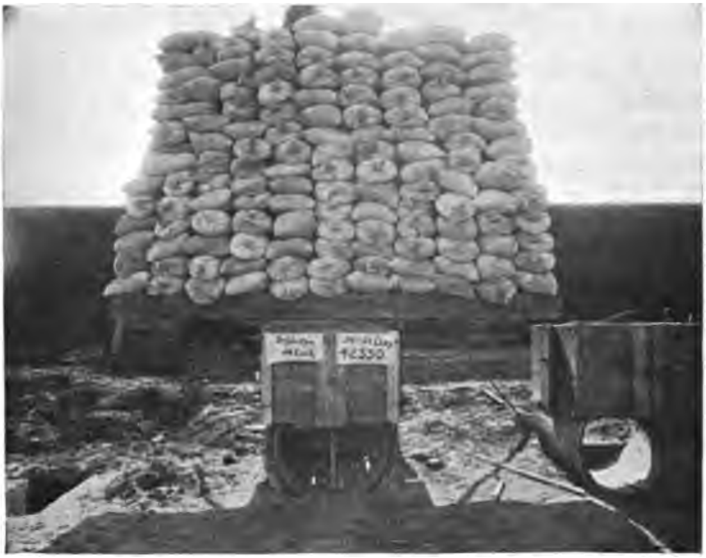

FIG. 113. CONCRETE PIPE CAN BE MADE VERY STRONG.

This figure should remove any doubt as to the strength that can be obtained in concrete pipe.

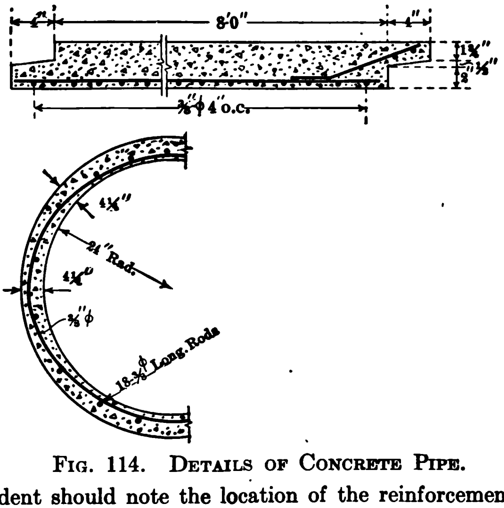

FIG. 114. DETAILS OF CONCRETE PIPE.

The student should note the location of the reinforcement and the details of the joint. (Culvert Pipe, C. & N. W. Ry.)

tudinal reinforcement amounting to about 1 **per cent** and **hooping** of about ½ **per cent.** In Fig. 114 the details of a typical concrete pipe are given.* Note the arrangement of the steel and the method used for jointing the pipe.

Prob. 99*a*. What is the weight of the concrete pipe shown in Fig. 114?

Prob. 99*b*. What per cent of longitudinal reinforcement is provided? Of radial reinforcement?

100. Problems for Review.

Prob. 100*a*. If concrete blocks were substituted for the brick in the Lawlor building, how many 8 × 12 × 16 inch blocks would be needed?

Prob. 100*b*. If you were to fence a lot 100 × 120 feet, how much steel, sand, stone and cement would you order if 6 × 6 posts, 8 feet long and spaced 10 feet o.c. were specified?

Prob. 100*c*. A 48-inch concrete sewer connects two points 328 feet apart. The specifications call for a 1 : 2 : 4 concrete. Make a purchasing schedule for the materials required.

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* Reinforced Concrete Culvert Pipe, C. & N. W. Ry.

CHAPTER IX

WALLS AND PARTITIONS

101. Classification of Brick. Ordinary bricks are made from some form of clay which is worked into a plastic condition and formed to shape, the plasticity later being removed by burning to the hard unchangeable brick. They may be classified in four different ways, namely: with regard to their **position in the kiln,** their **method** of **manufacture,** their **composition,** and their **position in the wall.**

When speaking of the kinds of brick as affected by their **firing,** we enumerate three sub-divisions: the **arch brick,** which are usually overburned and very hard and brittle, the **red brick,** which form about one-half of the contents of the kiln and are well burned and the best kind for all purposes of general use, and the **salmon brick,** which form the top layers of the kiln and are soft and underburned. Of these, the first variety, if not badly warped or too brittle, are the most durable and can sustain the greatest load, besides showing the greatest ability to combat the wear of the elements. The warped ones are very extensively used in the interior of piers and for brick footing courses. The salmon variety are undesirable for heavy work or for walls directly above grade and are used only for lining chimneys, for light wall construction, and for brick furring.

The various types of brick manufactured give us such trade names as **sand-struck, water-struck, wire-cut, pressed, re-pressed,** and **moulded.** In the early days of brick manufacture, when the work was done by hand, the moulds were dipped in sand or water to prevent the brick from adhering to the mould. In the former case we obtained the sand-struck brick and in the latter case we obtained the water-struck brick. The latter are sometimes called **slop-moulded** brick. This custom is still maintained in connection with modern machine-made brick and these two types are still specified. The **wire-cut** bricks are the product of the **stiff-mud** process, where the bricks are forced through a die in a stream and a wired wheel cuts the strip into the required lengths. If the strip is 2 × 4 in section, the bricks are called **end-cut,** while if the section of the stream is 2 × 8, they are called **side-cut.** In some cases the clay comes from the die 4 × 8 in section, and in this case the bricks are called **face-cut.** Pressed bricks are usually made from the **dry-clay** process. The moulds are of the desired section and are filled to a height slightly greater than the finished third dimension, a plunger adjusted to the proper size, forcing the clay into the die. This results in a very hard and compact brick. Many so-called pressed bricks should be properly called repressed brick. Moulded brick are the result of pressing clay into the shaped moulds and can be had in many shapes and sizes. They include in their class **arch brick, circle brick,** and the **radial blocks** from which chimneys are frequently made.

The materials from which bricks are made vary almost as greatly as the firing and the manufacture. When pressed bricks are made of a **prepared sand and lime mortar,** the ordinary **sand-lime** brick results. If the bricks are moulded and pressed from a mix of **cement mortar,** we have the common variety of **cement brick. Fire clay** in various combinations is used extensively in the manufacture of **firebrick,** which are used in lining fireboxes and in places where high temperatures are encountered. Many methods have been used for **facing** bricks with various glazes or by burning **slips** into the faces of the brick. This is the process by which the **glazed** and **enamelled** bricks are made. Another type of brick distinguished from the rest is the **paving brick.** They are made similarly to the ordinary brick with the exception that they have a different method of firing. They are burned to **vitri-**

fication and then **annealed** by slow cooling, making them extremely hard and tough and repellent to water.

Bricks are again classified with respect to their position in the wall. From this source of differentiation we speak of **stretchers, headers, closers, soldiers,** and **bull-headers.** A stretcher has its 2 × 8 face lying horizontally in the plane of the wall. The header has its 2 × 4 face in this position. The closer is a quarter or three-quarter brick which is used to make the courses line up symmetrically near corners and jambs in the wall. **Soldier** and **bull-header** are trade names used for the position of the 2 × 8 and 2 × 4 faces respectively when they are placed vertically in the plane of the wall. (See Fig. 115.)

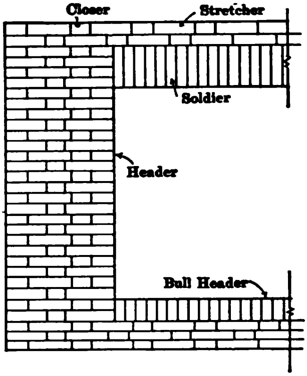


FIG. 115. CLASSIFICATION OF BRICKS AS AFFECTED BY THEIR POSITION IN A WALL.

102. Manufacturing Processes. The processes of manufacture of ordinary brick are generally divided into three types:

(1) **Soft-mud** process.
(2) **Stiff-mud** process.
(3) **Dry-clay** process.

In general these may all be said to involve the mining of the clay at the bank, the working of the clay in large breaking pits, passing the clay through pugmills which cut it up very finely and force it through the dies in a steam. It passes under the cutting wheel on to a continuous belt, from which it is carried to air drying spaces, after which it is burned in either **up-draft, down-draft,** or **continuous** kilns. These processes are very interesting and if the student has access to a brick yard it will be well worth his while to visit one.

103. Properties of Brick. The **color** of common brick depends upon the clays from which they are made, as well as the temperature at which they are burned. Pure clay free from iron will burn **white,** the presence of lime also producing this color to a great extent. Iron in the clay produces tints varying from a **light yellow** to an **orange** and **red** according to the amount of iron present. A clear **bright red** shows a large percentage of the oxide of iron, while an excess of iron and lime produces a **cream** or **light drab** effect. The presence of magnesia results in a **brown** firing color and when the two metals occur together in the makeup of the clay the bricks are **yellow.** The color of pressed bricks is the same as that for common bricks made from the same clay, but artificial colors are now added to produce almost any desired tone. These colors must of course be **mineral pigments.**

The fact that the manufacturers of brick in this country have not standardized the size of bricks often causes a great deal of trouble. The size varies with the locality and even with the manufacturers in the same locality. In New England the **commons** average $7\frac{3}{4} \times 3\frac{3}{4} \times 2\frac{1}{4}$. In most of the Western States **common** bricks measure about $8\frac{1}{2} \times 4\frac{1}{8} \times 2\frac{1}{2}$ and as a result the walls there are not 8, 12, 16 and 20 inches thick, but are 9, 13, 17, 21. Even in one lot the size will vary with the position the brick had in the kiln. Pressed bricks are more uniform in size as most of the manufacturers use the same kind and size of moulds. The prevailing size for pressed bricks is $8\frac{3}{8} \times 4\frac{1}{8} \times 2\frac{3}{8}$ inches. They are also made $4 \times 12 \times 1\frac{1}{2}$ in size, in which case they are called **Roman brick or tiles.** Pressed brick should be made of such a size that two headers and a joint will equal one stretcher, and it is advisable that they should be of such a thickness that three of them will equal, with the mortar joints, the length of one brick. The National Brickmakers Association has adopted $8\frac{1}{4} \times 4 \times 2\frac{1}{4}$ as the size for commons, $8\frac{3}{8} \times 4 \times 2\frac{3}{8}$ as the standard for face brick, $8\frac{1}{2} \times 4 \times 2\frac{1}{2}$ for paving brick, and $12 \times 4 \times 1\frac{1}{2}$ for Roman brick.

The weight of bricks varies with the kind of clay used and with their size. Commons average 4½ pounds each, while face bricks vary between 5 and 5½ pounds each.

Generally speaking, a good building brick should be free from cracks and flaws, sound, and should contain no lumps of any kind, or any free lime. They should be uniform in size and shape to insure neat brickwork, with all angles sharp and square. They should be burned to incipient vitrification in order to insure a hard, compact brick. Such a brick will give out a ringing sound when struck with a brick hammer. A good brick will not absorb more than 10 per cent of its weight of water. As a rule the harder the brick the less water it will absorb. Very soft bricks will absorb from 25 to 35 per cent of water. Weak light red ones will absorb from 20 to 25 per cent, while the best bricks will absorb only from 4 to 5 per cent. A brick may be considered good if it absorbs only 10 per cent.

104. Erecting Brickwork. In order to build any piece of brickwork so as to make it stable and durable, a bed of mortar is necessary on all the faces of all bricks which are in contact or adjacent to the faces of other bricks. The strength of a piece of brickwork as well as its durability depend upon:

(1) The quality of the brick.
(2) The quality of the mortar.
(3) The manner in which the bricks are laid.
(4) Whether the bricks are laid wet or dry.

For ordinary brickwork on small buildings a mortar composed of lime and sand is often used. It is always better, however, to use a certain proportion of cement in all mortars as the additional cost is well offset by the decidedly greater strength of the work. For brickwork laid below grade either an hydraulic lime or a cement mortar should be used.

The function of mortar may be divided up as instrumental in:

(1) Keeping out moisture and temperature changes by filling all openings.
(2) Uniting the whole into one mass.
(3) Forming a cushion to equalize the stresses.

The first function is attained by thoroughly grouting or flushing up all joints. The union of the mass depends upon the inherent strength of the mortar itself as well as upon the workmanship. The third depends largely upon the thickness of the mortar joints.

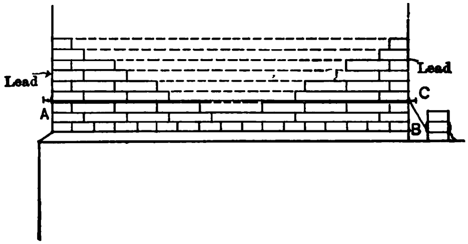


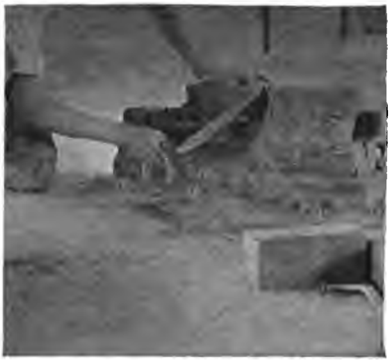
FIG. 116. LAYING UP BRICK WALLS.

The "leads" are laid up first, and are properly gauged and plumbed. The line is then stretched from the nail *A* to the nail *C* and is held fast as shown at *B*. The intermediate courses are then laid to this line.

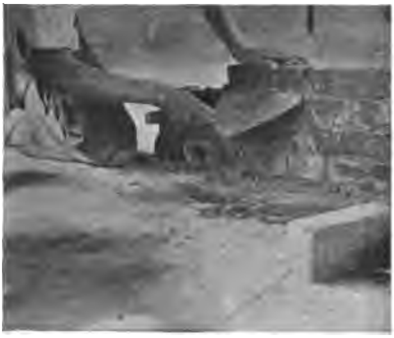
In the construction of a brick wall it is customary to follow a certain procedure. The important features of such work are the **maintenance of a regular bond, equal sized mortar joints, plumb and level faces,** and **well-filled joints.** Some of these features are definitely specified in the building codes and very commonly written into the specifications.

Brick may be laid with joints made by **shoving** or **buttering.** The joint most commonly specified is the shoved joint and this undoubtedly produces the well filled crevices mentioned in item (1) above. It avoids, at the same time, the additional labor of grouting the joints. The buttered joint is good if well done and if the workman is careful to **fill all the joints** in each course before going on to the next course.

In laying up the work shown in Fig. 116, the mason lays up the corner A and the jamb B in order to form gauge (*a*) The brick is bedded in mortar and pressed down with the left hand and the projecting mortar "cut" with the trowel.



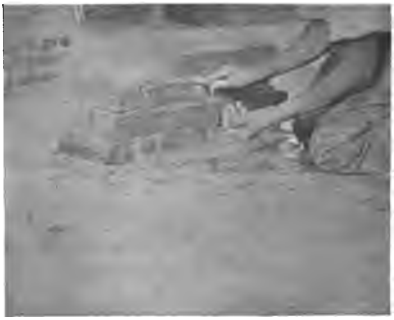
(*a*)



(*b*)

(*b*) The joint is then struck with the trowel as shown, or

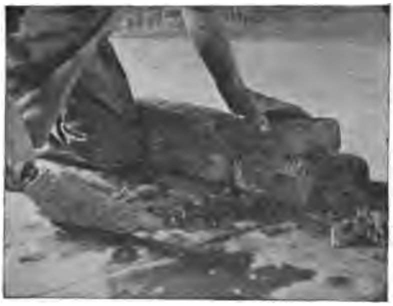
(*c*) It is struck with a jointer, later.



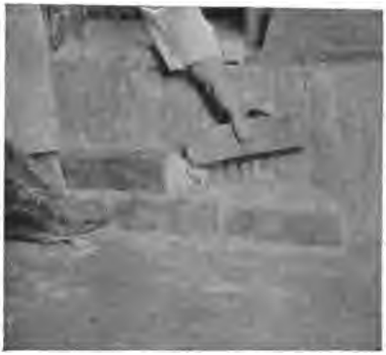
(*c*)

Fig. 117. Bricklaying.

lines for filling in. The course which starts such a wall is a header or bond course and only enough bricks are laid at



(a)



(b)

Fig. 118. Vertical Joints in Brickwork.

(a) The shoved joint. The bricklayer shoves enough mortar ahead of the brick to form the joint in this case.

(b) The buttered joint. In this case the previous brick is struck with a small amount of mortar, as shown, or the new brick is struck with the mortar for the joint. In placing the brick, this mortar forms the vertical joint.

each **lead** to bring the wall up to the second bond course. This work requires the use of a **course gauge** which is an ordinary lath marked off into equal spaces, one for each course. As each mason on a lead for the same wall has such a course gauge the wall is bound to go up level. The mason's level and plumb are used to make the leads plumb, and great care must be taken to see that this work is done cautiously. The filling of the courses to these leads is done by means of a **line** to which the bricks are laid. This line is raised, course by course, by fastening it to a nail around the corner and stretched taut.

The **striking** of joints is often done as the bricks are laid, in which case it is done with the trowel as shown in Fig. 117b. More often, however, the joint is just **cut** to the face of the brick, as in Fig. 117a, and after about 3 or 4 courses are laid the mason points them with a **pointer** or **jointer** as shown in Fig. 117c. Fig. 118 shows the laying of a shoved joint (a) and a buttered joint (b).

Often bricks are very porous and absorb a great amount of moisture. In the summer when the sun heats and dries the brick they become very absorbent, needing much water to keep them saturated. This property causes poor brickwork inasmuch as the water necessary for the hardening or setting of the mortar is removed from it by the brick if laid dry. For this reason all bricks for immediate use should be **thoroughly saturated with water** before using, especially if stored in the hot sun.

(*Perform Job No. 120, Vol. II.*)

105. Setting Pre-Cast Sills. The **setting** of pre-cast stone should follow the practice used for cut stone. The ends of the sill are bedded in mortar, so that the top of the sill at the **lug end** is just flush with one of the courses of brickwork, as in Fig. 119. The wood **wedges** (b) are driven into the joint to bring the sill level and to the proper height and are removed after the mortar has set sufficiently hard to carry the weight of the jambs and the frame. The joint is then pointed in a manner similar to the ordinary brick joints as discussed above.

At times the unit stone is too heavy to handle by hand and a **derrick** must be used. If the stone is long, there is danger of cracking it if lifted at the center. A double grip is then

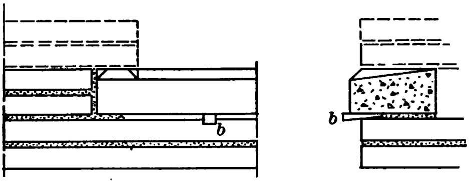
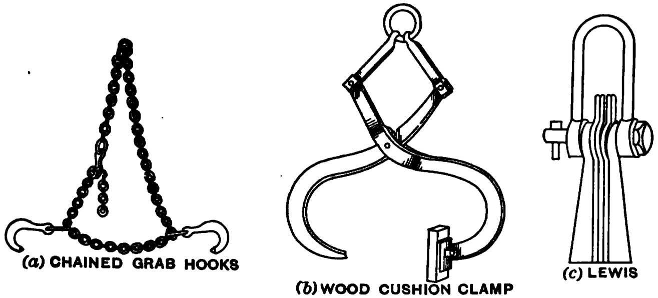


FIG. 119. SETTING A STONE SILL.

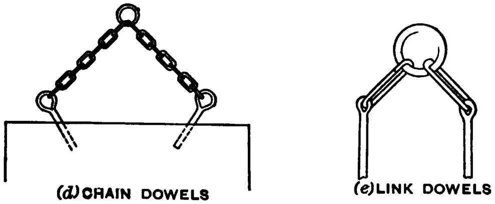
The sill is bedded in mortar at the two ends and is leveled by means of wooden wedges.



(a) CHAINED GRAB HOOKS

(b) WOOD CUSHION CLAMP

(c) LEWIS



(d) CHAIN DOWELS

(e) LINK DOWELS

FIG. 120 *. CLAMPS USED IN SETTING STONES.

(*a*) and (*b*) are commonly used where they will not obstruct the setting of the stone. (*c*), (*d*), and (*e*) are used for setting stones when it is desirable to keep the piece free from projecting tools.

provided for its placing. The most common types of clamps used for this purpose are called **grab-hooks, dowels, clamps and**

---

* (Taken from Howe's "Masonry.")

lewises. These clamps are shown in Fig. 120. The advantage of the dowels and the lewis is that the stone may be dropped into place between other stones. The importance of getting the stone correctly into place the first time cannot be exaggerated. If this is not done it must be sledged into place by light blows from a wooden hammer or stick.

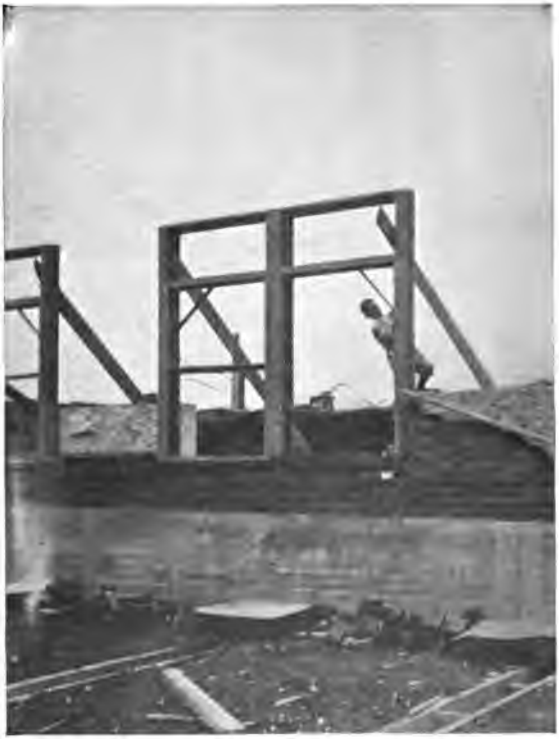


FIG. 121. SETTING A WOOD FRAME.

It is important to make sure that the frames are set plumb. They are braced in place, as shown, and the brick jambs are built around them.

106. Setting Wood Frames in Brick Walls. The importance of having window and door frames **plumb** necessitates care in erection. The frame is set upon the sill and is centered according to the plans. It is then stayed and braced in a plumb position by nailing directly to some nearby floor or joists, or by nailing to stakes or blocks set in the concrete paving, if that is placed beforehand. Fig. 121 illustrates one double-hung frame of a building, with all the braces, in place. The student will profit greatly by carefully noticing such work on buildings whenever he has an opportunity.

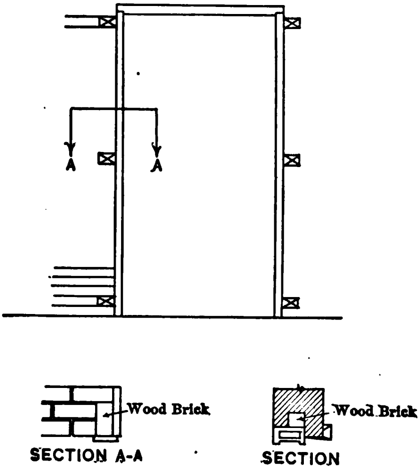


FIG. 122. NAILING BLOCKS FOR FRAMES.

Nailings must be provided for frames. Wood bricks, lath inserts, and wooden plugs are common nailings.

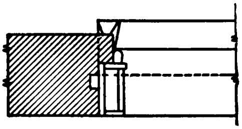


FIG. 123. CLEATED FRAME.

Frames are often secured in place by bedding cleats, which are spiked to the back lining of the frame, directly into the brickwork.

The jamb must be nailed to the brickwork, and this **nailing base** is customarily provided in the form of **wood bricks** set into the wall as shown in Fig. 122, which also provide a nailing for the finish. Sometimes frames are milled with dovetailed **cleats** at the jamb, as shown in Fig. 123 in section, and the brickwork is built around this frame, the frictional bearing providing the necessary fastening.

When all the frames are set in any story, the brick walls are carried up to the heads of the windows in the usual way, after which the lintels are formed and cast, or, if of pre-cast or cut stone, are set. Door frames are set in a very similar manner, and the student should work out a plan and elevation of door (Plate II) shown on the general plans.

107. Steel Sash. The industry in steel sash has grown rapidly and has met with extraordinary success. The modern factory is virtually a maze of steel windows set into the structural frame. The different kinds of stock sash manufactured are similar to those made by the Detroit Steel Products Company of Detroit. Mich., called "**Fenestra.**" Some of the others which are being used with success are the "**Truscon**" the "**United,**" the "**Bayley**" and the "**American.**"

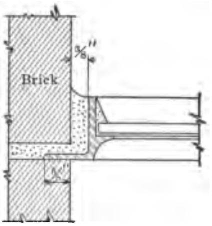


FIG. 125. SECTION OF BRICK JAMB SHOWING THE RELATION OF THE STEEL SASH TO THE BRICKWORK.

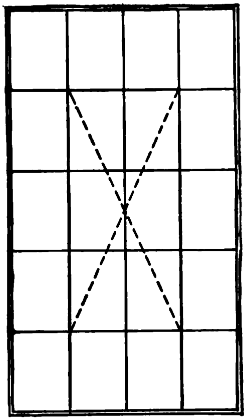


FIG. 124. STANDARD STEEL SASH.

Steel sash are indicated on the elevations of the building by lines. The crossed area indicates a ventilator.

They are all based upon the principle of **steel rails and stiles** with ventilating devices of one kind or another.

The sash is standard and is based in size on the number of lights in width and in height for varying sizes of glass. The sizes of glass used are 10 × 16, 12 × 18, and 14 × 20. The Detroit Steel Products Company numbers its sash by giving the lights wide, lights high, number of ventilators, panes per ventilator, and the number of panes the ventilator is placed up from the sill. For example the sash shown in Fig. 124 would be numbered 45161, which is based upon:

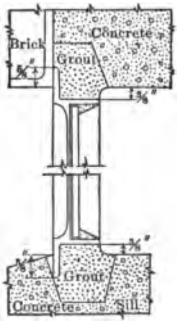


FIG. 126. DETAILS OF THE CONSTRUCTION OF THE HEAD AND SILL FOR STEEL SASH ERECTION.

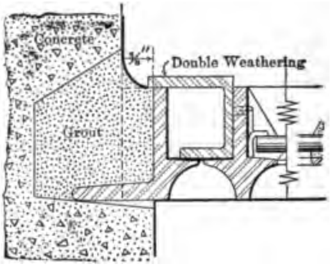


FIG. 127. POCKETS FOR STEEL SASH IN CONCRETE PIERS OR COLUMNS.

4 lights wide
5 lights high
1 ventilator
6 lights in the ventilator
1 light above the sill.

Plates XV and XVI are reproductions from the Detroit Steel Products Company's catalogue of their standard sash. The student will note the sections through the various parts of the sash, as these are very important in determining the exact details of construction.

The setting of steel sash varies with brick and concrete

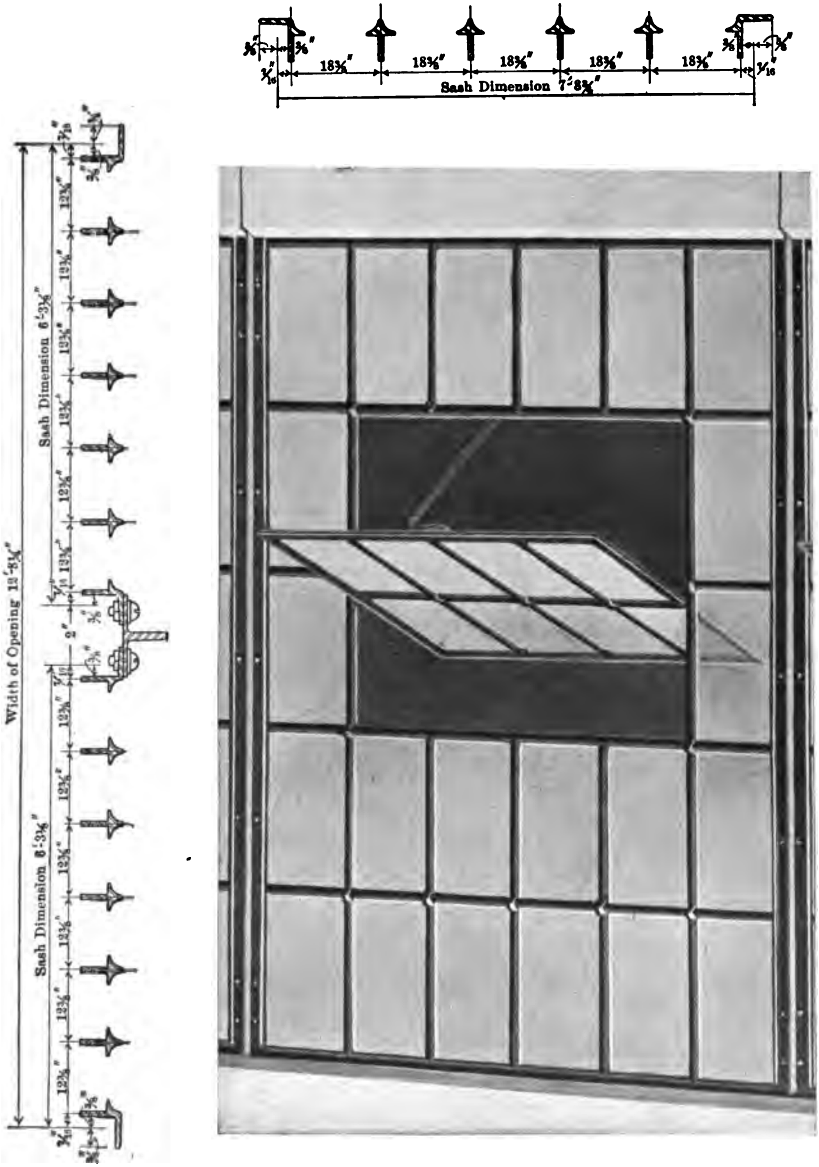
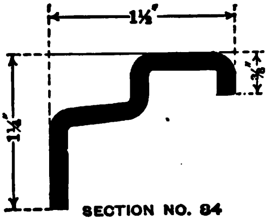
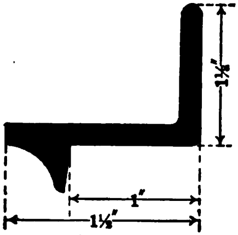


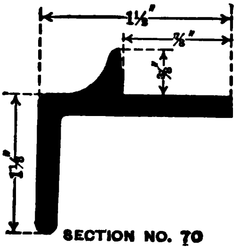
PLATE XV. DETROIT FENESTRA SASH.



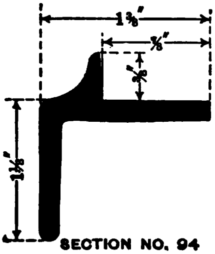
SECTION NO. 84



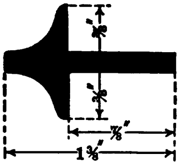
SECTION NO. 71



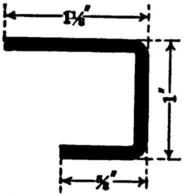
SECTION NO. 70



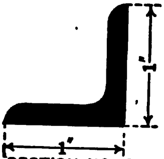
SECTION NO. 94



SECTION NO. 90



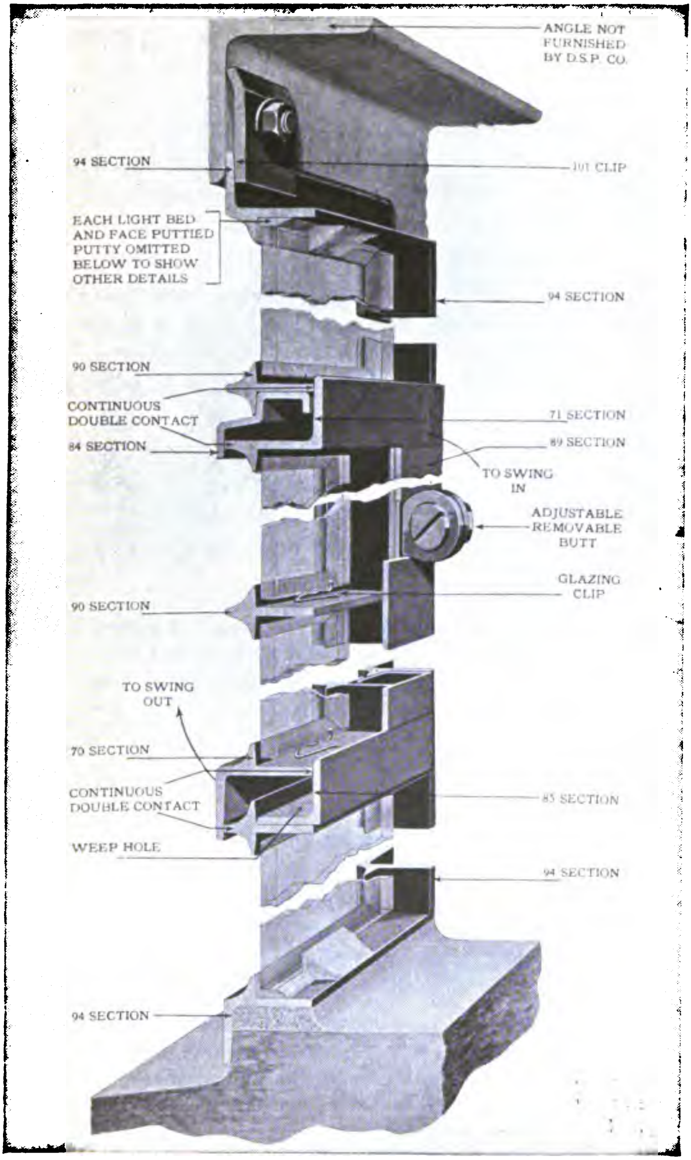
SECTION NO. 89



SECTION NO. 85

Plate XVI. Vertical Section T

Sta


ANGLE NOT FURNISHED BY D.S.P. CO.
94 SECTION
101 CLIP
EACH LIGHT BED AND FACE PUTTIED PUTTY OMITTED BELOW TO SHOW OTHER DETAILS
94 SECTION
90 SECTION
CONTINUOUS DOUBLE CONTACT
84 SECTION
71 SECTION
89 SECTION
TO SWING IN
ADJUSTABLE REMOVABLE BUTT
GLAZING CLIP
90 SECTION
TO SWING OUT
70 SECTION
CONTINUOUS DOUBLE CONTACT
WEEP HOLE
85 SECTION
94 SECTION
94 SECTION

Through Fenestra Sash with Details of the dard Sections.

walls. When set into brick walls, they are put into place the correct distance above the floor by **blocking up**, and are braced similarly to wood frames. The brickwork of the jamb is then carried up, allowing the **lug** of the sash jamb **to frame into the joints** of the wall, as shown in Fig. 125. When the walls are up to the proper height, the lintel is cast over as for wood frames, allowing the head lug of the sash to project into the forms. The sills for steel sash windows are always cast later. The construction of the work at the sill and head lines is shown in Fig. 126. When the sash is to be set into a concrete frame, it is not inserted until later. The piers are formed with **wedge-shaped pockets** into which the sash can slide, which are as shown in Fig. 127. The lintel is also provided with a similar pocket and the sash is slid into these from the slope side and then the frame is **pointed into place.** The sills are cast afterward, while the sash is held up in place by blocking as for brick wall construction.

Prob. 107*a*. Make a steel sash schedule for this job. It is customary to include with this schedule an elevation of one of each type and to letter each type *A*, *B*, *C*, *D*, etc., repeating these letters upon the elevations, or plans, or both.

(*Perform Jobs Nos. 122 and 123, Vol. II.*)

Prob. 107*b*. A 21-foot intermediate bay of a building with 12-inch walls is to be supplied with the maximum of sash width in 14 × 20 glass (Z size), but the area of brickwork required for pier load is 200 square inches. What combination of steel sash could you use to the best advantage?

Prob. 107*c*. Ventilators, if possible, should be kept from extending to the extreme masonry joint of the sash. Show by a sketch how you would ventilate a 3-unit sash composed of two 45142, and one 55162 units. What percentage of ventilation would this give?

Prob. 107*d*. A brick pier is set in cement mortar which allows a bearing of 175 pounds per square inch. The load the pier must carry is 100,000 pounds, and the c. to c. distance of piers is 20 feet. The sash is to be a 16-light, 3-unit width of 12 × 18 inch glass. How wide must the brick pier be?

108. Casting Sills under Steel Sash. The forms required for sills which are to be cast under steel sash are simple, but must be properly made in order to insure sharp edges and proper alignment. The form for the sills under the steel sash in this building is shown in Fig. 128. (Note the bracing and supports.) The concrete is cast into this form to within ½ inch of the top. A mixture of 1–2 facing mortar is then placed and trowelled to the proper wash and surface as for walks. The forms are stripped as soon afterwards as practicable, and the sill is surfaced according to the finish desired.

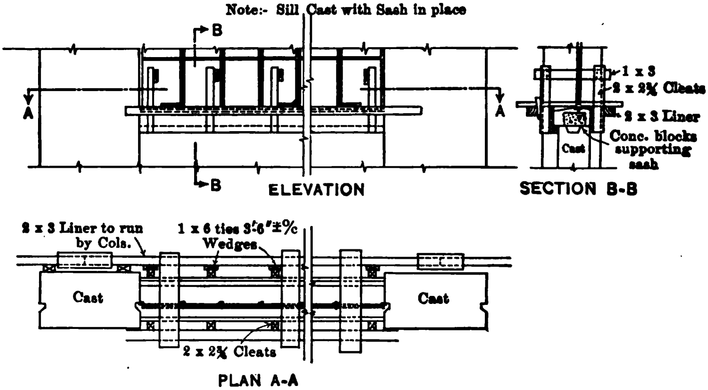
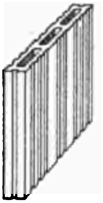


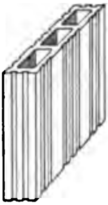
FIG. 128. FORMS FOR A SILL BENEATH A STEEL SASH.
Note the method of supporting the sash.

109. Structural Tile. Tile for structural purposes is made of clay, sand, and coal in a similar manner to brick and can be bought in varying thicknesses and shapes. The National Fireproofing Company, the Pennsylvania Tile Company and the Dennison Tile Company manufacture such tile with either a plain ribbed, or scored and dovetailed surface, and Plate XVII is furnished by the courtesy of the National Fireproofing Company showing their standard hollow tile blocks. The advantages of hollow tile are lightness combined with great strength, and provision for hollow walls without the

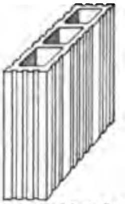
NATCO PARTITION TILE



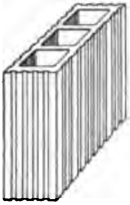
2x12x12—Weight 16 lbs.



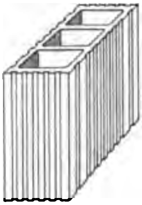
3x12x12—Weight 16 lbs.



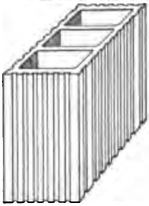
4x12x12—Weight 18 lbs.



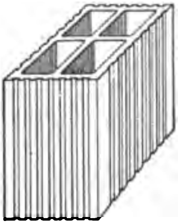
5x12x12—Weight 21 lbs.



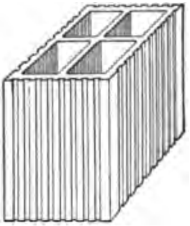
6x12x12—Weight 24 lbs.



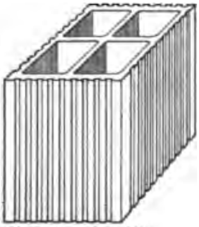
7x12x12—Weight 29 lbs.



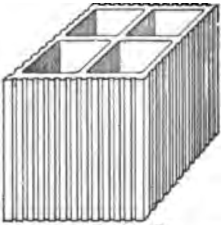
8x12x12 (4 cell)—Weight 32 lbs.



9x12x12—Weight 36 lbs.



10x12x12—Weight 38 lbs.



12x12x12—Weight 42 lbs.

STANDARD SIZES AND APPROXIMATE WEIGHTS OF PARTITION TILE
Weights given for estimating purposes only—they vary at different factories.

PLATE XVII.

excess cost in labor necessary, when this property is a matter of erection, as in hollow brick walls.

Prob. 109*a*. If structural tile weighs 0.72 pound per square inch of cross section, what is the cross-sectional area of a 4 × 12 × 12 inch tile?

Solution. From Plate XVII the weight of a 4-inch tile is 18 pounds. The cross-sectional area would therefore be:

$$18 \div 0.72 = 25 \text{ square inches.}$$

Prob. 109*b*. Make a table such as indicated below.

Tile.	Weight per foot.	Area of sections.
4		
6		
8		
10		
12		

110. Setting Tile. Hollow tile should always be **set in a cement mortar** and with the **openings and webs vertical.** This is not always done, but the strength of tile when set horizontally is much less than when set vertically. The wall is laid similarly to brickwork but lays up much faster, because the placing of one block does not require much more time than laying 2 or 3 bricks and covers one square foot of wall, whereas about 20 bricks are required to make the same face area in a 12-inch wall. The manner of setting is somewhat different from brickwork, however. The horizontal joint mortar is placed upon the tile already in place and the vertical joint mortar is then faced upon the tile as it lies in a horizontal position. The mason then sets the tile by placing it in the position shown in Fig. 129. It is then tapped with his hammer or trowel handle in order to make a snug joint which is pointed as the tile are set.

Careless workmen waste considerable mortar in placing the horizontal joint. The surface upon which this can be lodged is very small and sometimes a layer of **metal lath** is placed upon this surface before the tile is set. This is a little more expensive but gives the wall great lateral strength. The lath for this work can be bought in the widths desired at a slightly higher unit price. Fig. 130 illustrates such a lathed joint.

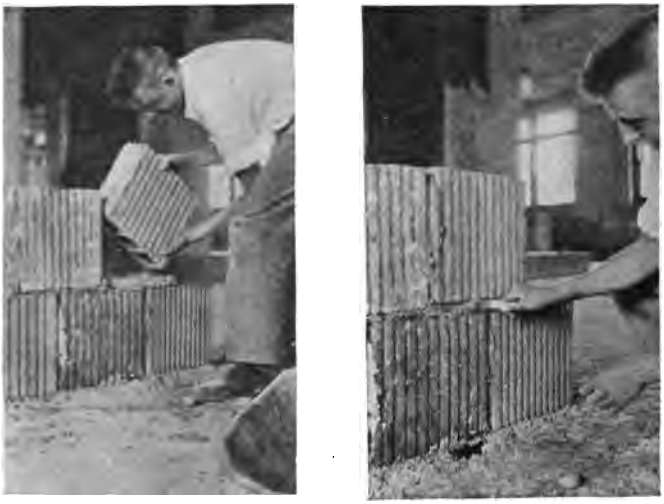

(*a*) (*b*)

FIG. 129. SETTING TILE.

The tile is faced with the mortar for the vertical joint and is dropped into place as shown at (*a*). The joints are then filled and pointed as shown in (*b*).

Another seeming disadvantage of tile is the difficulty in cutting it. Manufacturers now provide natural **cleavages** across the walls, but at times it is necessary to cut the piece parallel to the webs. The best manner of doing this economically is to fill the tile opening in which the cut is to occur with packed sand and then to tap it carefully with a sharp brick hammer or cold chisel. This should be done all around the tile before any smart blows are struck. It is then possible to have the tile split true and without injury.

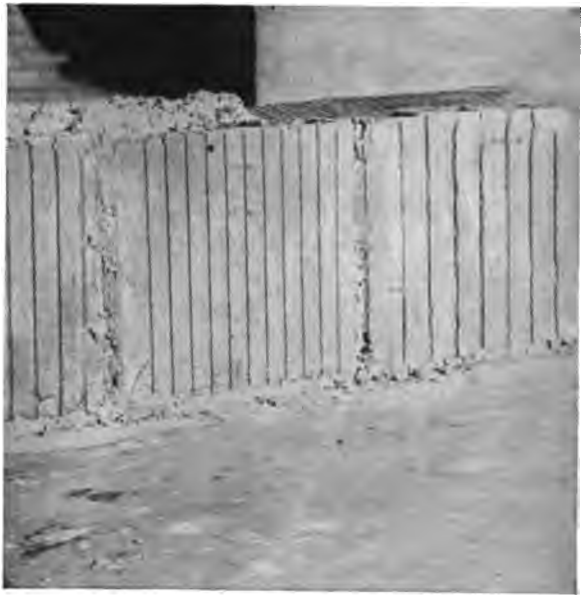


Fig. 130. Lathed Tile Joint.

Tile walls are stronger when set as shown here, but it is hard to bed the mortar upon the horizontal "withes" of the tile. The use of a metal-lath strip for this purpose not only facilitates erection but gives the wall greater lateral stability.

(*Perform Job No. 121, Vol. II.*)

111. Tile Lintels. Where it is necessary to span door and window openings with tile, they must be combined into

a reinforced lintel, which is pre-cast. A wood form is provided to secure proper alignment, as shown in Fig. 131. This form is tilted backward at an angle and the first tile is placed at the bottom. The side which is to be reinforced (usually the outside) is then marked for future reference and the concrete is poured to fill the openings, the steel rod being in place. The mortar joint is then placed and the next tile is slipped over the rod and similarly filled. This is continued until the lintel is about **12 inches longer than the span** of the opening. When this has set sufficiently for handling (about 7 days), it is placed as a unit lintel.

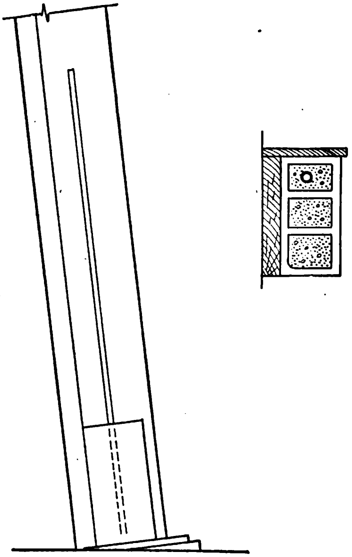


Fig. 131. Casting a Tile Lintel.

A simple method for building a unit concrete-filled tile lintel is to set the first tile in a form, as shown, and to fill the openings with concrete. The reinforcement is then forced into place. A mortar joint is bedded and the second tile is slipped over the rod. This is filled with concrete, and so on, until the proper number of tile are set. The tension side of the lintel, which should have the steel, is marked for placing.

112. Setting Frames in Tile Walls. Frames may be set previous to the erection of tile walls or they may be inserted after these are in place. The latter method is used mostly where wood frames are to be erected and this necessitates a proper nailing in both the jambs and the lintel. Many schemes have been devised for this work, some using **steel plugs or strips** and others **wood plugs and strips.** The use of wood for this work is simpler and is accomplished by **setting lath strips in the joints** as the wall is carried up, or by **drilling** the tile wall **for plugs later.** The strip is more satisfactory than the plug, as the drilling of tile results in a very narrow grip for the plug, the tile spalling on the inside. Fig. 132 shows an isometric of a tile wall jamb with these strips in place. The strips in the lintel are placed when it is pre-cast.

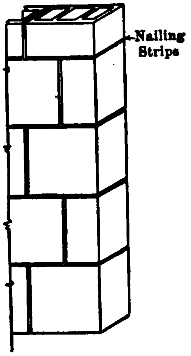


FIG. 132. NAILING STRIPS FOR FRAMES IN TILE WALLS.

These are usually short lath strips bedded directly into the mortar joints. Three should be provided for each jamb.

113. Wood-Stud Partitions. The plans and specifications for this building call for **wood-stud partitions** around the office. The student is more or less familiar with this type of construction and it is only necessary to discuss such points as are of special application here. The wall should be erected after the floor and roof slab are in place, and these concrete parts should provide **nailing pieces** at the proper location. The nailing in the floor paving can be a bevelled 2 × 4 set

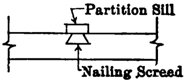


FIG. 133. NAILING STRIP FOR THE PARTITION AT THE FLOOR LINE.

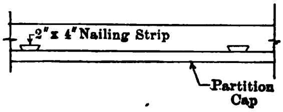


FIG. 134. NAILING STRIP FOR THE PARTITION CAP IN THE BOTTOM OF THE SLAB.

flush in the concrete as shown in Fig. 133. The blocks for the nailing of the partition cap at the ceiling will be small and spaced about 4 feet apart. (Fig. 134.) At the columns the best method is to drill and plug, but the method of locating wood blocks as for the slab is also in use.

Fig. 135 illustrates the framing elevation of the wall between Column 5 and the front brick wall of this building.

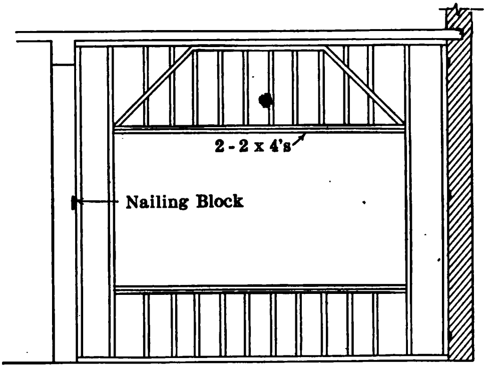


Fig. 135. Framing Elevation of Office Partition.

The studs in this work should be 2 × 4's. Note the method of bridging the head of the sash and the nailing provided.

This shows the **bridging** required, the location of **structural head and sill** 2 × 4's, and the **plaster stops** or **grounds** for the nailing of the partition trim.

114. Metal Plaster Lath. Plate XIV, Chapter VI, gives the various kinds of plaster lath that may be used for this portion of the work. The **ribbed lath** provides a raised lath and is advised for such plastering as this. It is fastened to the frame by staples as shown in Fig. 136, and the sheets are lapped at their ends as shown. The lath is stopped on **wood grounds** which are placed for **leveling purposes** and for **furnishing nailing** for the trim. They should be at all trim points and thick enough to equal the thickness of the raised lath rib and the plaster coat, as shown.

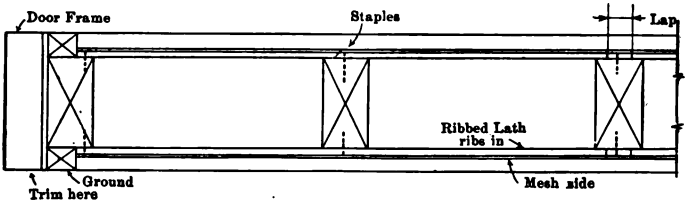


Fig. 136. Plan of Metal-Lathed Partition.

The lath is fastened to the studs with the ribs in and is stopped against plaster grounds of the thickness required by the specifications. Note that the door-frame is equal in width to the thickness of the wall, from plaster face to plaster face.

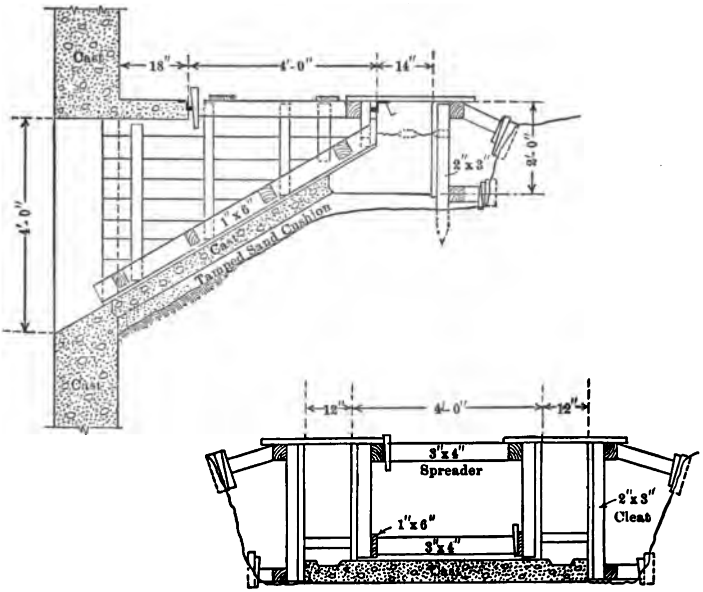


Fig. 137. Forms for the Coal Chute.

Note the method of wiring, wedging, and bracing.

115. Setting Iron and Steel Frames in Concrete. While studying the erection of frames and sash, it is worth our while to look into the placing of the **cast iron frames and steel parts** of this building. These occur at the base of the chimney, the coal door, and the shipping door sill shown on the plans. Forms for the construction of the coal chute are shown in Fig. 137 and these indicate the relation of the frame to the concrete. These steel parts are often placed into pockets left for future erection, but this practice is bad and precludes a perfect bonding of new and old concrete. If this work is done as shown in Fig. 138, it may result in a lasting job, the concrete edges indicated by dotted lines being placed later.

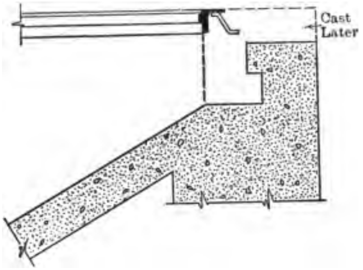


FIG. 138. SETTING STEEL FRAMES INTO CONCRETE.

This can be accomplished by setting the frame directly into the form as shown in Fig. 137, or it can be cast in later. The first concrete when cast, is "toothed" or "lugged" as shown.

(*Perform Job No. 69, Vol. II.*)

116. Problems for Review.

Prob. 116*a*. What is the percentage of ventilation in a steel sash made up of 2–54161 and 2–64181 units?

Prob. 116*b*. Draw a vertical section of the sash illustrated on Plate XVI, assuming that it is a 45142 unit. (12 × 18 inch glass.)

Prob. 116*c*. A tile lintel is cast for a 6 foot opening, of 8-inch tile. Determine the amount of cement, sand and stone which is necessary to do this work.

Prob. 116*d*. Make a schedule of the metal lath required to furnish a base for the plasterwork on the wood stud partitions for this building.

Prob. 116*e*. How many pounds of steel in the coal chute for this building?

CHAPTER X

CONCRETE WALKS AND PAVINGS

117. Walks. The use of concrete for walks and pavements is becoming more general daily. The careful contractor pays as much attention to this part of his building operations as he does to the building itself. He must provide a walk which will not **crack** by **settlement, contraction** or by **upheaval** due to **frost** or the **roots** of trees, and one which is **mixed** and **cured** in such a manner as to prevent the **scaling** or **crumbling** of the surface.

(Perform Job No. 100, Vol. II.)

118. Bedding of Concrete Walks. The proper bedding of walks is of as much importance as the laying of the concrete. The **foundation** should be from 6 to 12 inches deep, depending upon the nature of the soil. To prevent settlement cracks, the **ground** should be thoroughly **rammed** after excavation, in order to provide a solid bearing. Upon this a layer of crushed stone, hard cinders or other hard, porous material, such as broken tile or brick, is placed, and this is **thoroughly tamped** with the proper slope for **drainage** of the foundation. This provides room for the expansion of the water in freezing. If the foundation is to be in clay soil, which holds water and heaves greatly when frozen, it should be provided with side outlets or drains of tile at convenient points which lead to dry-wells, thus allowing the surrounding earth to soak up the water. Roots of trees which are less than **18 inches** below the surface of the ground should be cut away in order to prevent upheaval.

119. Base Concrete. The coarse concrete forming the bulk of the walk is usually 4 inches thick and should be composed of a **1–2½–5 mix** of a consistency which is just wet enough to allow the water to come to the surface under the tamping. The concrete should have an aggregate of gravel or crushed stone which will pass a ¾-inch mesh screen and which will be retained upon a ¼-inch screen, sand which is free from loam, and coarse, and some standard Portland cement which will meet the specifications as laid down by Committee C–9 of the American Society for Testing Materials. This concrete should be **laid off in squares** not to exceed 36 square feet (6 × 6 feet), **separated by joints** which pass clear **through** the slab and which are from ⅛ to ¼ inch wide. This allows enough room for expansion and permits of the replacing of an individual block, if the necessity arises, without disturbing the adjoining ones.

(*Perform Job No. 104, Vol. II.*)

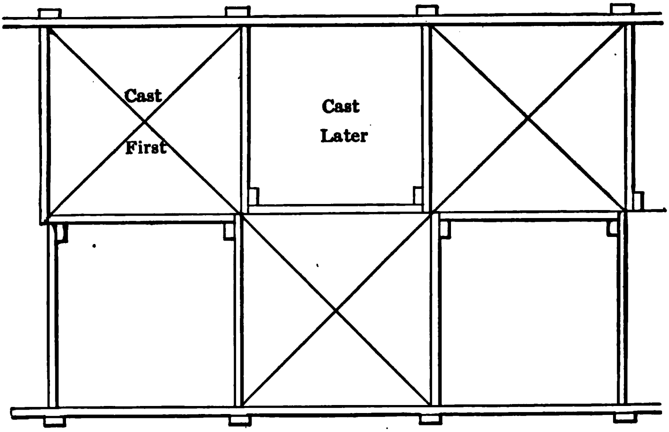


FIG. 139. CASTING CONCRETE PAVING IN SECTIONS.

When concrete walks are cast in this fashion, the development of "through joints" is inevitable. If this precaution is heeded the walk will not crack across a square, but along a construction joint.

120. Laying the Base Concrete. Three methods have been used successfully by contractors in placing concrete for walks. In the first the **alternate blocks are placed** by forming

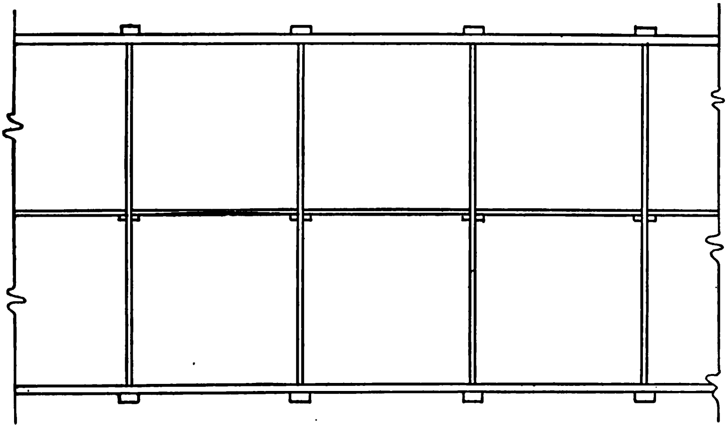


FIG. 140. CASTING THE ENTIRE WALK AT ONCE.

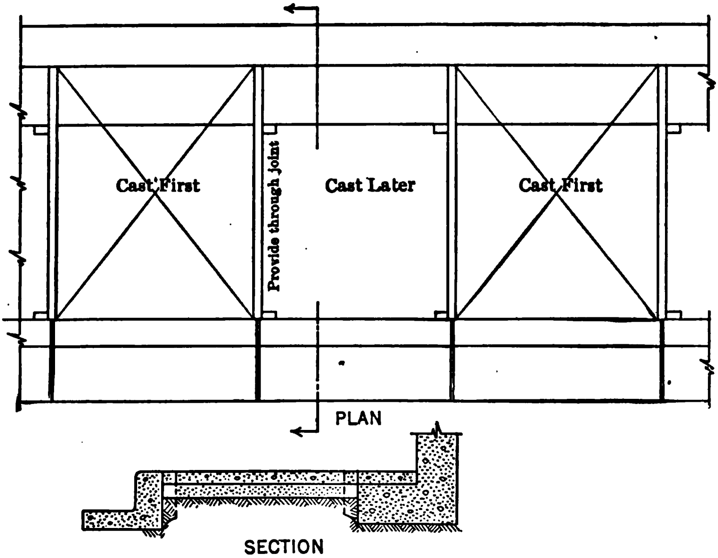


FIG. 141. METHOD OF FORMING THE WALK OF THE LAWLOR BUILDING.

Compare with Fig. 139.

as shown in Fig. 139, after which the remaining blocks are cast. In the second the **entire walk** is **formed** with 2 × 4's and 1¼ × 4 cross pieces and all is cast at once. (Fig. 140.) The 1¼ × 4 pieces are then removed and the joints filled with a lean mortar or sand. The third method provides the **joints by** using **tarred paper.** The first method is the one most commonly used and may be said to be preferred. In our building the walk is 6 feet 4 inches wide and would be formed as shown in Fig. 141. Joints should always be provided around all trees and about 6 inches from the building, manholes, and other adjacent structures.

121. Surface Coat. Frequently walks are placed in one operation called **one-course** work, in which case the mix of the concrete is a 1–2–3. When **two-course** walks are specified the surface **granolithic** must be composed of materials so graded as to give good wearing quality. The Aberthaw Construction Company of Boston has evolved the specification given in Chapter II under "Pavings," which has given excellent satisfaction. This surface coat is placed before the base has attained its initial set and is composed of a 1–2 mortar of cement and trap rock in which no sizes larger than ½ inch are used and from which all material which will pass a No. 30 mesh screen is removed.

The finish is spread with a **strike board,** floated with a **wooden float,** after which all laitance and superfluous water is removed. After this has set for about 4 or 5 hours it is floated **once** with a steel trowel, removing all pits, blow-holes, bubbles, and other such defects, **no further working being allowed.**

122. Surfacing Tools. The tools used for concrete finishing are the **strike board,** the **wood float,** the **steel float,** the **jointer** and the **edger.** The strike board is used as shown in Fig. 142. It is run transversely across the 2 × 4's with a saw-like motion in order to make the surfacing level. The latest specifications of the American Concrete Institute call for the striking of the surface to within ½ inch of the established

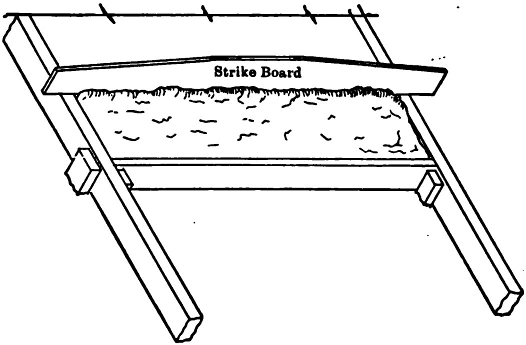


FIG. 142. STRIKE BOARD LEVELING.
After the surfacing mortar has been placed upon the concrete base of a walk, the strike board is drawn over it to remove all surplus mortar and to bring the surface to a plane.

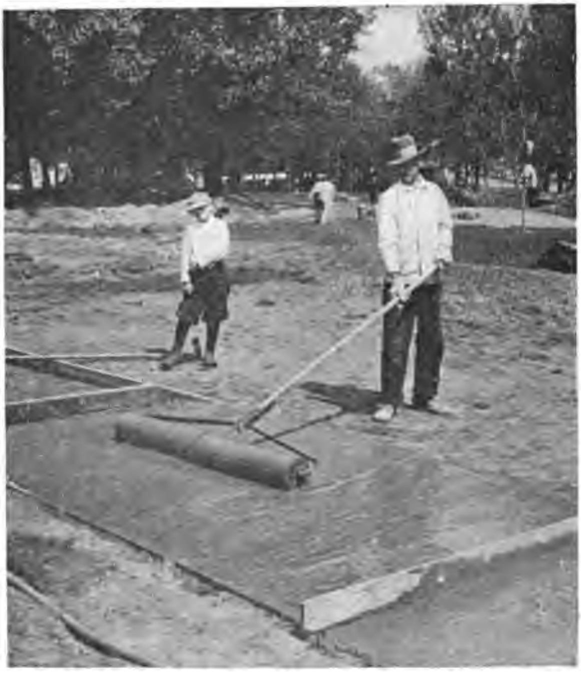
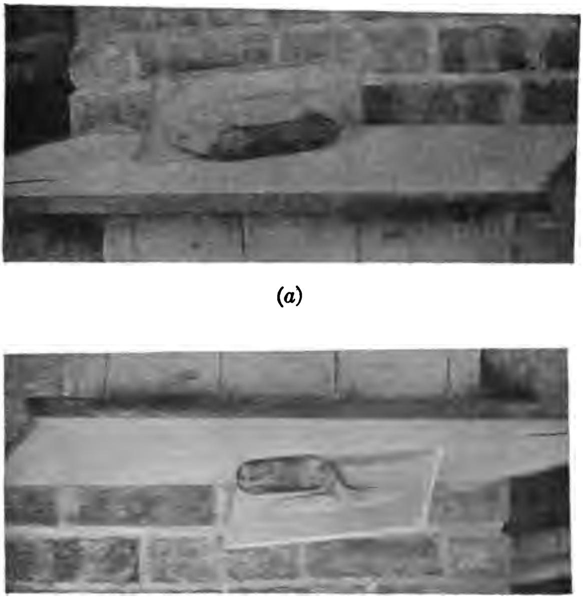


FIG. 143. ROLLER FINISHING OF WALKS.
Instead of finishing the walk surface with a steel float, the roller is often used. It removes the surplus water and compacts the finish mortar.

grade, after which the walk is rolled longitudinally with a metal roller slightly longer than the span of the block and from 6 to 12 inches in diameter. This process is repeated at 15-minute intervals until all the excess water is removed.



(a)

(b)

FIG. 144. FINISHING TOOLS.

(a) The wood float or "darby" is used after the surface of the walk has been struck.

(b) The steel float is used after the darby and at a time when the mortar has just obtained its initial set. The fewer strokes necessary to make a satisfactory finish, the better.

This method makes a compact, smooth, dense surface and does away with the use of the wood float. The roller method is illustrated in Fig. 143. When the strike board is used without the roller, the wood float illustrated in Fig. 144b is employed. This is passed over the surface in a circular

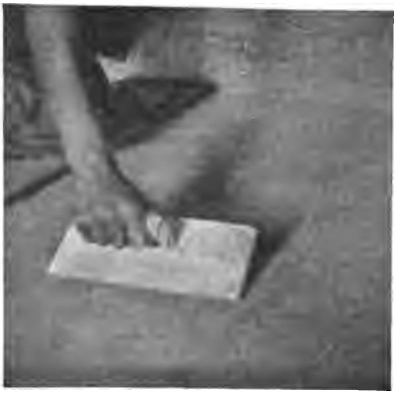
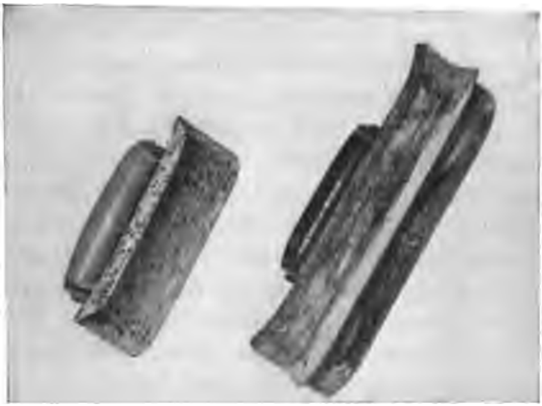


FIG. 145. POSITION OF STEEL FLOAT IN FINISHING.



(*a*) (*b*)

FIG. 146. JOINTING TOOLS FOR WALKS.

The markings, or joints, in a cement walk are obtained by cutting them with a trowel and then running them with either the edger (*a*), or with the jointer (*b*). The former is used for the outside edges and the latter is used to make the interior joints.

motion until all pits and defects are removed and until the surface is even and of a uniform texture. The concrete is then allowed to set and the steel float, illustrated in Fig. 144a, is used similarly to the wooden float, the last stroke of the tool being a circular one so made as to remove any trowel marks and in order to leave a smooth glossy surface. The position of the float for this work is shown in Fig. 145. The joint between two blocks is made with the jointer, Fig. 146b, and the side joints are made with the edger, Fig. 146a. These two tools are run along a straight edge to insure perfect alignment.

(Perform Job No. 105, Vol. II.)

123. Weathering and Wearing Qualities of Concrete Surfaces. Moisture and temperature are responsible for volumetric changes in the concrete. The former is more often the cause of cracks than the latter. The use of too rich a mixture for surfaces results in the separation of the finish from the base, as a lean concrete is affected less by moisture and temperature changes than a rich mixture. It is therefore advisable to make the surfacing as lean as possible, practically. It is also an advantage to make the surfacing as thin as possible (never less than ½ inch) so that the base will be affected by the changes in weather conditions as nearly equitably as possible with the surfaces. This will result in many small cracks, if cracking occurs at all, rather than large open structural cracks. Precautions should be taken to procure as good a bond between the base and the granolithic as possible. Excessive troweling should be guarded against, as this brings a layer of neat cement to the surface which will later peel off and produce dusty and pitted work.

The resistance of a granolithic coating to abrasion is as much dependent upon the hardness of the aggregate as it is upon the tenacity of the cement. Abrasion will wear away the cement and sand grains or will pull the aggregate out of the cement matrix. When the sand is a very hard one, the wearing quality of the surface is greatly increased with the increase in the sand content, but the amount of cement binding the various grains together decreases. The limit is reached in a 1–2 mixture. When the surfacing is a part of the structural slab, the question of an abrasive concrete arises. The same holds true here as in mortar granolithic. The **proportions of the mix** therefore **determine the quality of the surface,** and the two important items are a **maximum proportion of hard aggregate** and a **minimum amount of cement** to effectually coat all the grains.

The following suggestions from Mr. L. C. Wason, President, Aberthaw Construction Company, in a paper on Dustless Concrete Floors are valuable also as applied to sidewalks.

The smallest particle of sand which will withstand ordinary wear is about $\frac{1}{8}$ inch diameter.

The surface should be about 90 per cent aggregate and 10 per cent cement.

If mortar is mixed too dry, the surface is porous and the aggregates, not being well bonded, will work loose, producing a dusty surface. If the surface dries too rapidly, it will be impaired in quality and will dust. If mortar is mixed too wet the water rising to the surface brings up the fine particles of cement and a soft spongy substance called laitance, which wear rapidly. Sprinkling the surface with cement and sand to dry it is detrimental. The glaze that results from too prolonged finishing will wear away quickly.

A top coat applied after the base has set will wear rapidly. New cement will not bond to old hardened cement. It will bond to cleaned off aggregates in old work.

A coat of boiled linseed oil will cure a floor surface that dusts up. The use of water glass or silicate of soda is recommended.

124. Curbs and Gutters. Section 8, Plate I, shows the construction of the gutter and curb for the street walk for this building. The use of concrete for curbs and gutters has the distinct advantage of **minimum excavation** and the **possibility of ease in alignment.** The blocks should be made in approximately 6-foot lengths and the vertical joints should pass **clear through the block** to the bedding. All the precautions mentioned in connection with the walk hold true in this case. In addition to this, great care must be exercised to provide for drainage to sewers.

125. Curb and Gutter Forms. Fig. 147 illustrates in part-plan and section the forms for the curb and gutter for this building. It is customary to form and cast these parts before the walk is laid. The extreme side forms are set in place first and the gutter concrete is placed. When this has set for about three hours, the intermediate form is set and the curb concrete is placed. After about two hours the top surfacing of the curb is cast and leveled. The intermediate form is then removed and the face of the curb and the gutter are cast in granolithic. The usual method of surfacing with the wood and steel floats is then resorted to.

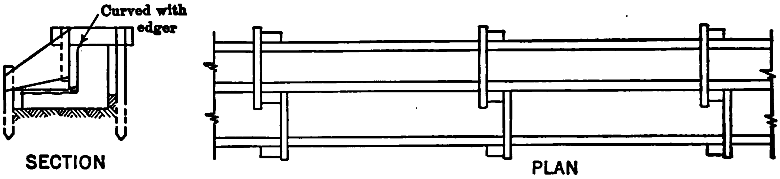


Fig. 147. Forms for Concrete Gutter.

Proper alignment of gutters is important. The exposed finished surfaces should be made with a 1 : 2 mortar and backed with the concrete.

(Perform Job No. 106, Vol. II.)

126. Staking Out Corners and Lines. The ordinary steel tape can be used to lay out corners for buildings and to extend lines for walks, by the application of the relation which exists between the three sides of a right triangle. We learn from geometry that the **squares of each of the two legs of a right triangle when added will give the square of the other side or hypotenuse.** Hence, if we considered a right triangle with two legs of 3 feet and 4 feet respectively, we would have the following equation for the relation of the three sides:

$$3^2 + 4^2 = 5^2.$$

This is a convenient relation worth remembering. The student will see that it also holds for 6, 8, 10, and 12, 16, 20 and so on. In order, therefore, to stake out a right angle for a building this relation may be employed. To locate the four sides and corners of a building on a lot the procedure would be as follows:

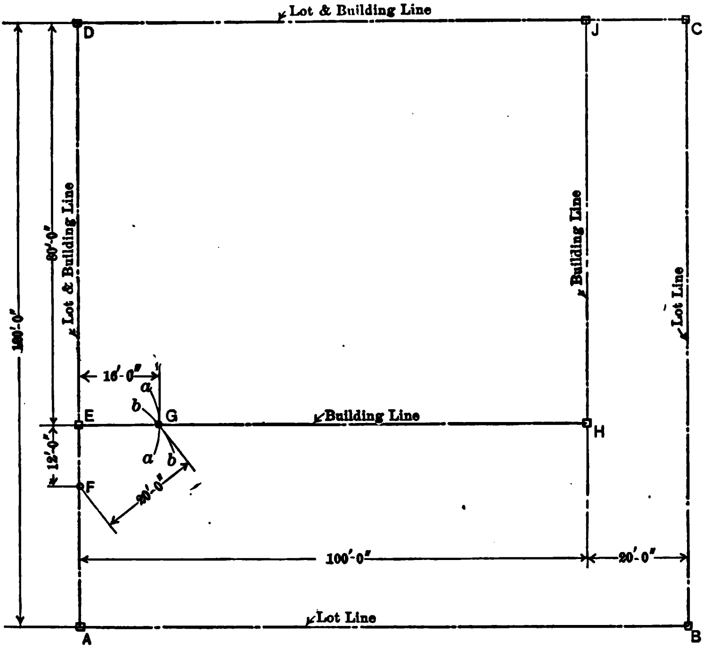


FIG. 148. LOT AND BUILDING LINES FOR THE LAWLOR BUILDING. Building lines which are at right angles to each other can easily be located by the use of the steel tape.

The points *A*, *B*, *C*, and *D* (Fig. 148) are determined by a reference to the surveyor's stakes and the surveyor's plot plan. The distances of **120 feet** are checked accurately with the tape.

The line AD is definitely established by stretching a line between the stakes. The dimension of **80 feet** for the depth of the building being more important than the remaining **40 feet**, more or less, the steel tape is used to measure this distance from the point D. A stake is then driven and set plumb beneath the line AD at the point E. With the **12-foot** mark on the tape accurately over E, the point F is located on the line AD. With the **16-foot** mark on the tape over the point E, the arc "*aa*" is struck through G. With the **20-foot mark** on the tape over the point F the arc "*bb*" is struck through the point G. The actual intersection of these arcs is the point G. The line EG is then at right angles with the line AD. By stretching a line from E to H so that it is plumb over the point G we have the front building line forming a right angle corner with the line of the building on AD. The distance EH is then measured and the stake H driven correctly. The same operation is repeated at H as at E and the accuracy of the work can be seen by the nearness to coincidence of this line HJ with the point J as located by measurement along the line DC.

(*Perform Jobs No. 12 and 101, Vol. II.*)

Prob. 126*a*. What is the distance from D to H in Fig. 148?

Solution.

The distance DJ is 100 feet.
The distance JH is 80 feet.
The diagonal DH is equal to

$$\sqrt{\overline{DJ}^2 + \overline{JH}^2} = \sqrt{\overline{100}^2 + \overline{80}^2} = \sqrt{16{,}400} = 128.07 \text{ feet.}$$

Prob. 126*b*. Is the distance EJ equal to the distance DH? Why?

Prob. 126*c*. If the horizontal distance between two points is 165 feet 3 inches and the distance up a slope to a point directly over one of them from the other is 201 feet 6 inches, how much higher is the ground at the top of the slope than at the bottom of the slope between these points?

Prob. 126*d*. In Fig. 148, it is desired to locate a point 36 feet from the *EH* building line toward the *DC* building line and distant 26 feet from *E* toward *H*. How would you use the steel tape to locate this point?

127. Batter Boards. These boards are located at each corner of the building as shown in Fig. 149 and are placed about 4 or 6 feet from the building lines. The posts are usually 2 × 4 stakes set so that they are all in a vertical plane and $\frac{7}{8}$-inch sheathing is nailed to them so that lines may be stretched as shown. The line is held by two men and two others using plumb-bobs give the direction of movement to insure the placement so that it is directly over the points *D* and *E*. In this way all the lines of the building are run and the excavation may proceed or the lines may be established as the case may be.

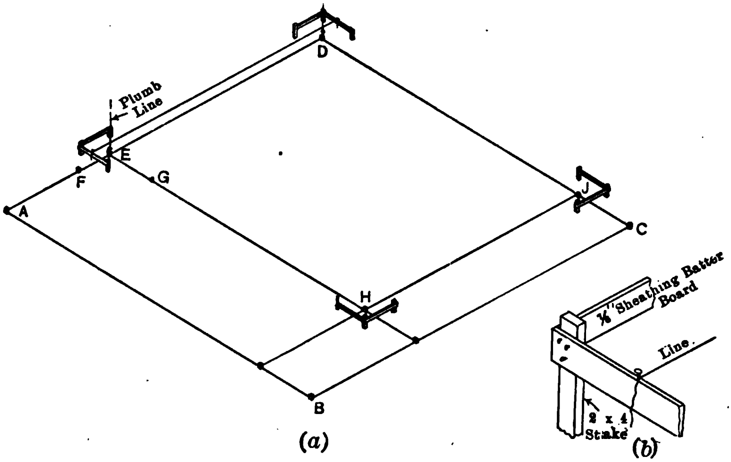


Fig. 149. Batter Boards.

128. Leveling. The leveling of the gutter is accomplished by the use of the engineer's level and rod, and the elevations must be checked and approved by the city authorities. The use of these two instruments is of enough importance to the builder to repay him for the time necessary to acquaint himself with them.

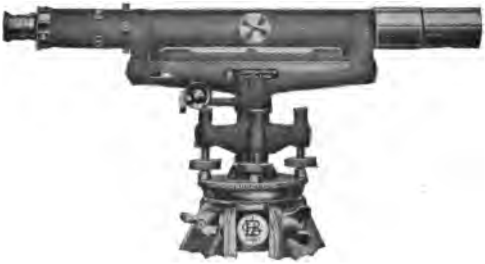


FIG. 150. THE BERGER DUMPY LEVEL.

This type of level will stand much rough usage. When it is out of adjustment it must be corrected by the manufacturer.

The two types of levels in use generally are the **Dumpy** (Fig. 150) and the **Wye** (Fig. 151). The dumpy is adjusted in the factory and will stand more rough handling than the wye, but when it is out of adjustment it must be sent back to the manufacturer for correction. The wye, however, can be

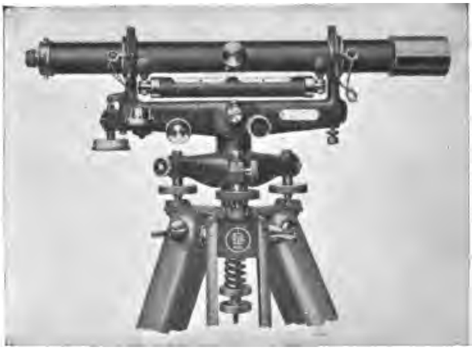


FIG. 151. THE BERGER PRECISE WYE LEVEL.

This instrument allows of adjustment by the engineer. The telescope is supported in two adjustable wyes.

corrected by the engineer by means of adjusting screws. The instrument is set up on a **tripod** at some convenient point and leveled by means of leveling screws. The **telescope** is placed in line over two diagonally opposite screws and these are turned either up or down to bring the **bubble** below the telescope into a level position, indicated by having both ends of the bubble an equal distance from the center of the vial. The telescope is then turned over the other two diagonally

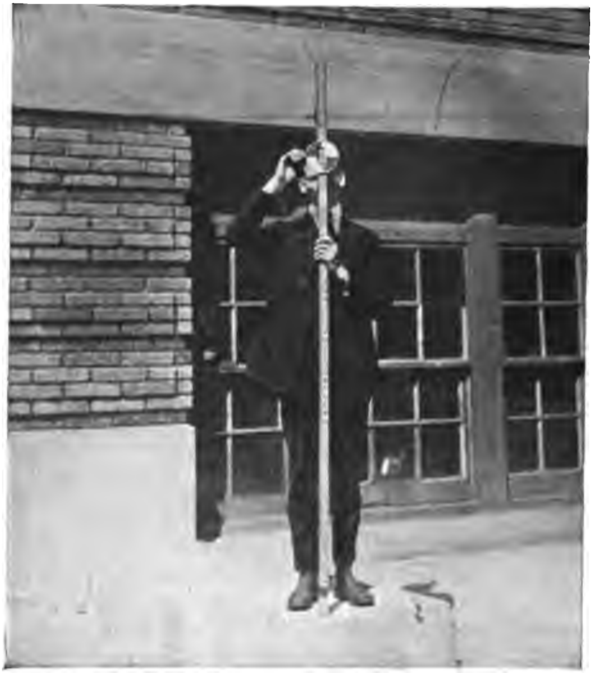


Fig. 152. The Level Rod.

This rod consists of a target mounted upon a rod which reads in feet, tenths of a foot, and hundredths of a foot. By means of the vernier, readings can be obtained to thousandths of a foot. The extension allows its use for differences of elevation up to thirteen feet.

opposite screws and the operation repeated. This whole operation is then repeated to insure a level telescope in any position on the axis. If care is taken to have the plate of the instrument horizontal to begin with, no trouble will be encountered in leveling.

The **rod** is an instrument with a target on which a **vernier scale** is attached giving a zero reading in line with the horizontal dividing line between the red and white quadrants. The rod is **divided into feet, tenths and hundredths of a foot** and by

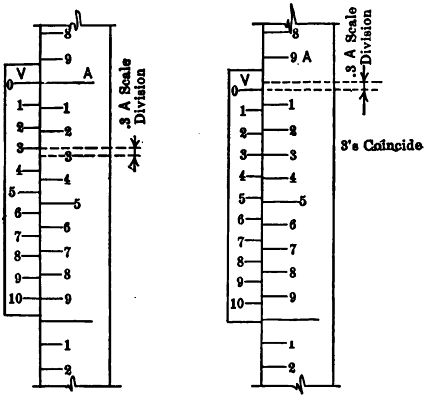
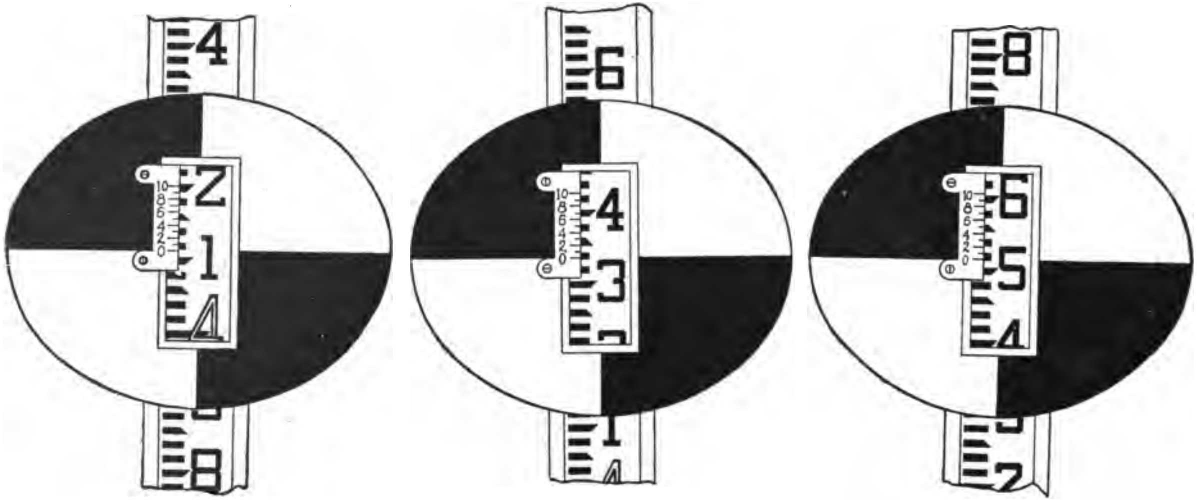


FIG. 153. VERNIER SCALES.

the use of the vernier **thousandths** of a foot can be read directly. (Fig. 152.)

The vernier is a scale which has been devised to read accurately tenths of a division. In Fig. 153 we have ten divisions upon the **main scale** *A*. If the **scale** *V* is so divided that **ten divisions upon it cover only nine upon the scale** *A*, **each** of these **units** will be **one-tenth of a large scale division smaller** than those on scale *A*. As we look down the scale, each vernier division will be as many tenths of the main scale division short of reaching the same main scale division as the number on the vernier. For example, the *V* scale division **3** will be **0.3 of an** *A* **scale division short** of reaching the same



(*a*) (*b*) (*c*)

FIG. 154. THREE ROD READINGS.

number on that scale. If we now move the *V* scale down until its **3 division** corresponds with the **3 division** on *A*, we will have moved the scale **0.3** of an *A* division. Thus if we move the *V* scale to a position where it coincides with the cross hair of the level telescope, we can read the tenths of the main scale divisions by noting the number on the *V* scale which corresponds exactly with a division on the *A* scale.

Fig. 154 shows three settings of a rod. The first indicates a rod-reading of **4.108**, the second **4.332**, and the third **4.511.** The student will profit by getting a rod and sliding the target to any number of points and determining the readings, having them checked by some competent person. Speed and accuracy in this work are more or less dependent upon experience and this the student must acquire.

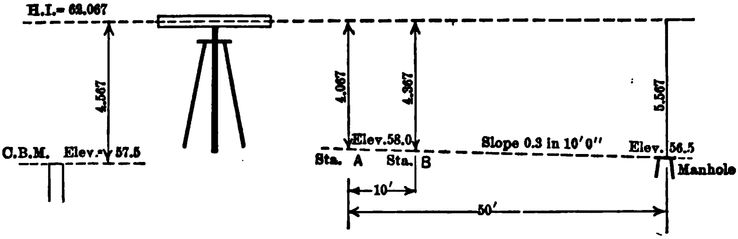
Using these two instruments for leveling requires a **starting point** or **bench mark.** The city can furnish the elevation of one of their nearby **monuments,** called **City Bench Marks** (**C.B.M.**) and from this as a base the contractor can set his rod for the elevation required. For example (Fig. 155):

Set up the instrument at some point where a reading can be taken on the **C.B.M.** Note the reading (**4.567**). The elevation of the **C.B.M.** from the records is **57.5.** Thus the height of the instrument (**H. I.**) is **4.567** plus **57.5** or **62.067.** The elevation of the curb at the east building line is **59.0** and the elevation of the gutter slab is **58.0.** The sewer manhole is **50 feet** west of this point and has an elevation of **56.5.** This means that the gutter must slope toward the sewer with a pitch of **18 inches in 50 feet,** or **0.3 foot for every 10 feet** of gutter. From this information we can determine the elevation of the form for the gutter at each of these **10-foot intervals.** The rod is then set to give the first elevation of **58.0.** This is done by decreasing the rod reading sufficiently to give the same H. I., or

$$58.0 + x = 62.067$$
$$\therefore \quad x = 4.067.$$

The form is then set so that the target zero line coincides with the telescope cross hair by bringing it up so that it will just touch the bottom of the rod. Ten feet further west the elevation of the gutter is 57.7. The rod is then made to read

$$62.067 - 57.7 = 4.367.$$



GUTTER GRADES							DATE WEATHER BY
STA.	+	H. I.		ELEV.	GR. ELEV.	GR. ROD	REMARKS & CALCULATIONS
CBM				57.5			
⅄	4.567	62.067					
A	4.067			58.0	58.0		Elev. given for Soil Gr. at A
MH	5.567			56.5	56.5		“ “ “ “ “ “ Manhole
B	4.367			57.7	57.7		Calculations
							Rod at MH 5.567
							“ “ A 4.067
							Sat. B - 10′-0″ from Sta. A Diff. — 1.500
							MH 50′-0″ “ “ “ Rod at CBM 4.567
							Fall = 3′-0″ per 100 “ “ A 4.067
							Diff. + .500

FIG. 155. THE USE OF THE ROD AND TABLE OF RECORDED READINGS.

This is repeated until the whole form is pitched toward the sewer. This work can be done by means of a line, but the sag in lines is troublesome and does not always insure proper alignment.

Prob. 128*a*. The rod reading on a C.B.M., with an elevation of 156.82, is 4.327. The rod reading at a stake 150 feet from the C.B.M. is 5.819. What is the elevation of the ground at the stake? What is the variation in elevation per foot assuming that the ground slopes uniformly? What per cent of grade is there (feet drop per 100 feet)?

(Perform Jobs No. 102 and 103, Vol. II.)

Prob. 128*b*. A gutter slopes from elevation 32.81 at a point 150 feet distant from a sewer manhole which has an elevation of 31.14. What is the pitch of the gutter per foot? What is the elevation of the gutter at a point 35 feet distant from the manhole?

Prob. 128*c*. A level is set up at Station A and a back-sight is taken on a B.M. of elevation 182.79. This gives a rod reading of 2.172. A fore-sight is taken on a stake No. 1, with a resultant reading of 6.328. The instrument is set up at Station B and the back-sight on stake No. 1 is 3.387, while the fore-sight on stake No. 2 is 7.839. What is the elevation of stake No. 1? What is the H.I. at Station B? What is the elevation of Stake No. 2?

Prob. 128*d*. If you continued the level traverse started in Problem 128*c* and returned to a position which would give you a fore-sight on the B.M., should the elevation of the B.M. by calculation equal the original elevation used? Give reasons for your answer.

129. Plain Concrete Stairs. The general method used on the sidewalk, curb, and gutter should be followed in protecting a plain concrete stair from the elements. Fig. 95 shows the forms used for the concrete steps in this building

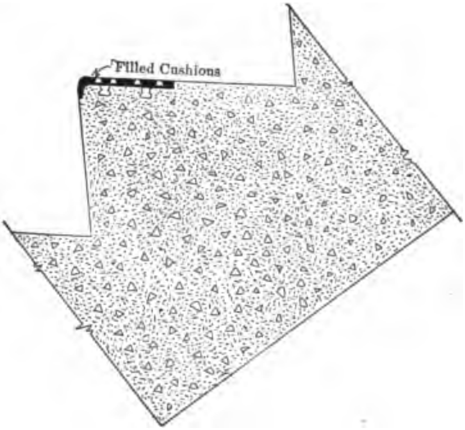


FIG. 156. SAFETY TREAD IN CONCRETE STAIRS.
These treads are provided with a "non-slip" filling.

and the student should note the methods of bracing and aligning used. The mix for this work may be a **1–2½–5 base** and a **1–2 granolithic.** Care in forming the **nosings** of the steps will prevent subsequent chipping and in order to **prevent slipping a safety tread** or rough finish may be **used** on the treads. Fig. 156 illustrates the placement of a safety tread in a stair slab, and it is always good practice to provide such a tread grip on public stairways.

130. Pavings. Probably no kind of concrete work receives more grinding, pounding, and general wear than a roadway paving. The points covered in connection with walks are even of greater importance here. The aggregate must be **well-graded, clean,** and **hard.** The **mixture** should be reasonably **rich,** the proportions advised being a **1–2–3** for **one-course work** and a **1–2½–5** for **two-course work,** as for walks. Where there is any doubt as to the sub-foundation, the slab should be **reinforced with one-tenth of one per cent of steel per foot** in the form of **mesh, fabric,** or **rods.** The sub-foundation should be uniform in texture and density and should be well wetted down and tamped. The concrete mixture as recently specified should be quite dry, the **viscosity** being **produced** by **tamping** and **mixing** rather than by an excess of water. Not enough stress can be laid upon proper **curing.** The pavements should be covered with sand or shavings kept continually moist for about **four weeks.**

The proper **drainage of roads** is important and is obtained by **crowning.** The usual crowning or rise at the center of a roadway is about $\frac{1}{100}$ **of the width.** The thickness of the slab varies considerably too, but this depends upon the traffic that the road is to carry. The **ordinary road** may be **5 inches thick** but some roads subjected to heavy and continuous traffic have been made as much as 8 inches thick at the crown. The **grade** of the road should not exceed **12 per cent,** and that provided the surface is rough.

It has been mentioned that the use of one- and two-course work is common. The one-course is a neater mix but does away with the surfacing, which causes the two-course road to be more expensive. It also provides a wearing surface which includes the coarse aggregate, which is an advantage. The sizes of the aggregate both for the coarse and the fine are much the same as for walks.

The importance of **joints for expansion** in roadways is undeniable. They should occur at every **50 feet** of roadway and should be from $\frac{1}{4}$ to $\frac{3}{8}$ inches wide. They should be **filled with** a plastic **pitch** or **tar** and should pass clear through the slab. If these joints are not filled with some plastic substance, they will eventually fill up with some foreign resistive material such as sand which, when expansion again occurred, would remove the advantage of the joint entirely.

The most complete description of recommended practice for roads is given in the **Report of the Committee on Concrete Roads and Pavements of the American Concrete Institute** and is here reproduced with illustrations through the courtesy of the Institute.*

(Arts. 131 to 141 incl.)

131. Materials.

1. Laboratory Control. Laboratory control, in order to obtain the greatest benefit, should be interpreted in a broad sense. Samples of all materials for use in concrete pavements should be tested in the laboratory. These samples should be representative of the supply, which necessitates some control over methods of sampling; also some provision should be made for field testing. This latter is essential especially on the fine aggregate, to insure that the material actually being used is practically as good a quality as the sample tested.

It is most advisable that all construction of concrete roads and pavements should be done under laboratory control. This control should extend to the testing, sampling, and a certain amount of field inspection, of all concrete materials. Testing and sampling are to be done prior to the acceptance of materials for use in any concrete road or pavement.

The object to be accomplished by laboratory control is to determine, prior to use, whether or not the materials available are of proper quality; also this would enable the laboratory representative to determine and suggest the proportions which would give the best results. All laboratory control must be based on certain tests of the constituent materials, of the finished concrete and an interpretation of such results.

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* Proc. A. C. I., Vols. XIV & XV, 1918 & 1919.

Cement. The American Concrete Institute has previously adopted the Standard Specifications for Portland Cement of the American Society for Testing Materials.

Fine Aggregate. Fine aggregate when used in the wearing course should be of a high grade and, although thickness of concrete and other factors would have to be regulated to meet traffic on different highways, the fine aggregate should be of the same class when used for surfacing on any concrete highway.

Fine aggregate should consist of hard, durable particles smaller than one-quarter inch in size. No tests have yet been perfected to determine the durability of fine aggregate and this will have to be determined by visual inspection.

We recognize that the present tests and test methods leave much to be desired. It is recommended that the following tests be made to determine suitability of fine aggregate for use in concrete roads and pavements:

1. Organic impurities (colorimetric tests).
2. Sieve analysis.
3. Mortar strength test.
4. Volume of silt.

Organic Impurities. It is a known fact that organic impurities which may be encountered in a few sands are likely to give poor results if such sand is used in concrete. A method for determining the existence of harmful organic impurities has been developed by Committee C-9 on Concrete and Concrete Aggregates, of the American Society for Testing Materials. This appears in Part I of the 1917 Proceedings of the American Society for Testing Materials, pp. 327–333, and is also printed in pamphlet form as Circular No. 1 of the Structural Materials Research Laboratory, Madison and Robey Streets, Chicago. Two methods for making the tests are described, namely, laboratory and field methods. The method for field tests, which in general are sufficient for this purpose, is given below.

Method for Field Tests. "Fill a 12-ounce graduated prescription bottle to the 4½ ounce mark with the sand to be tested. Add a 3 per cent solution of sodium hydroxide (NaOH) until the volume of the sand and solution, after shaking, amounts to 7 ounces. Shake thoroughly and let stand over night. Observe the color of the clear supernatant liquid.

"In approximate field tests it is not necessary to make comparison with color standards. If the clear supernatant liquid is colorless, or has a light yellow color, the sand may be considered satisfactory in so far as organic impurities are concerned. On the other hand, if a dark-colored solution, ranging from dark red to black, is obtained, the sand should be rejected and should be accepted only after it has passed the usual mortar strength tests.

"Field tests made in this way are not expected to give quantitative results, but will be found useful in

"1. Prospecting for sand supplies.
"2. Checking the quality of sand received on the job.
"3. Preliminary examination of sands in the laboratory.

"An approximate volumetric determination of the silt in sand can be made by measuring or estimating the thickness of the layer of fine material which settles on top of the sand. The percentage of silt by volume has been found to vary from 1 to 2 times the percentage by weight."

Sieve Analysis. The proper gradation of fine aggregate has a direct influence on the strength of concrete. A sieve analysis is useful in arriving at the proper proportions of the fine and coarse aggregate to be used in the mixture. There is at present no uniform practice in the number and size of sieves used for this purpose. Five or six sieves ranging from 100 mesh to 4 mesh are sufficient for this test. It is recognized that the present practice of placing definite limitations on the percentage of a sample passing certain sieve sizes is open to criticism. However, the limitations given in the current specifications for concrete roads and pavements of the American Concrete Institute would give satisfactory results, although certain sands which may not fall within these limitations might, if properly proportioned with coarse aggregate, also give satisfactory results.

Mortar Strength Tests. These are made to determine the hardening qualities of fine aggregate when mixed with Portland cement. It is recommended that this test be made on all samples of fine aggregate. The following methods of tests are recommended:

Compression tests on 2-inch cubes or 2 by 4-inch cylinders, on a mixture of 1 part cement to 3 parts of sand by either weight or volume. The volumetric method is considered more rational, since it approximates field conditions of proportioning. Parallel tests should be made by the same operator on standard Ottawa sand mortar, using the same cement. The test specimens should be stored under the same conditions.

As a basis for acceptance, the following relative strengths are recommended:

Age of tests.	Minimum strength of fine aggregate mortar.
3 days.	1.15 times standard Ottawa sand mortar strength.
7 days.	1.05 times standard Ottawa sand mortar strength.
28 days.	1.00 times standard Ottawa sand mortar strength.

Silt Tests. An excess of silt contained in the sand, although it may not affect the strength of the concrete, has a tendency to rise to the surface, resulting in a scaling of the top. Volumetric tests for silt determination are recommended. Although this method cannot be performed with the same degree of accuracy as the weight method, it can be more easily checked in the field.

As for the value of the above tests, organic impurities are detrimental to any sand for use in concrete. Gradation has a direct influence on the strength of concrete. An excess of silt is likely to result in a scaly surface. Organic impurities and gradation affect the mortar compression, and the latter might be considered a check on both organic impurities and gradation. The effect of the silt is one that can be determined in most cases only after concrete has been under service.

Coarse Aggregate. One method of test, known as the Devâl abrasion test, has been standardized and is at present in more or less general use for the testing of stone for all types of highway work. This has proved somewhat satisfactory for the testing of stone for macadam roads. It is questionable just how accurate it is for determining the suitability of coarse aggregate, both stone and pebbles, in concrete work. However, it is a fact that this test will indicate the difference in poor and good stone; and since as yet there are no suitable substitutes it is recommended that this test be used for determining the suitability of stone for use as coarse aggregate.

Several methods have been devised for the testing of pebbles to determine their suitability as coarse aggregate in concrete, but none of these are at present in general use. A recently designed improvement on the standard Deval stone abrasion machine has the standard cylinder replaced by one that is slotted, thereby eliminating the dust cushion. This latter machine is at present being used in the New York State Highway Department with good results in the testing of slags and pebbles, which have never given satisfactory results in the standard cylinder.

Hardened Concrete. Sampling and testing of concrete specimens cast in the field from material being placed is a valuable test not only on the aggregate being used but also on the manipulation. We recommend that provisions be made in the specification for the sampling and testing of field concrete. Specimens should be 6 inches in diameter and 12 inches long. Methods for making field tests may be found in the report of Committee C–9 on Concrete and Concrete Aggregates of the American Society for Testing Materials, Part I of the 1917 Proceedings, pp. 322–326. A pamphlet containing this report may be obtained from the chairman of the Sub-Committee on Field Tests, William M. Kinney, 111 West Washington Street, Chicago.

Sampling. Representative samples of the supply of coarse or fine aggregate proposed for use in concrete roads and pavements should be submitted to the laboratory for test. These samples should be taken by an engineer, preferably one who is familiar with sampling materials, so that he will know how to obtain a representative sample. Various methods have been developed for sampling fine aggregate, but these are so numerous — varying as the condition of the supply varies — that it would not be practicable to enumerate or describe them. Great importance should be attached to the proper sampling of all materials, especially fine aggregate. Full information should be furnished with these samples, giving the extent of the supply, and proportions of different kinds of materials which may occur in the supply. A test of any material is only as valuable as the sample is representative of the supply. Samples of fine aggregate should consist of one-half cubic foot of material passing ¼ inch. If run of product is sent in as a sample from a gravel bank containing particles above ¼ inch, the sample should consist of ¾ to 1 cubic foot of material. Samples of stone for use as coarse aggregate should be taken from an unweathered portion of the ledge and should contain 30 pounds of material.

2. **Cement.** Only Portland cement should be used in concrete pavements. It should meet the requirements of the Standard Specifications and Tests for Portland Cement of the American Society for Testing Materials. One sack of Portland cement (94 lbs. net) should be considered one cubic foot.

3. **Aggregates.** Durable, clean, well-graded aggregates are absolutely essential to the success of a concrete pavement. Uniform quality is of great importance. Samples of the materials proposed for use should be submitted to the engineer before orders are placed and tests should be made on these samples to see that the specifications are fulfilled, although this is not so essential if

aggregates from the source of supply in question are well known to be satisfactory and uniform in quality. Field tests for grading and cleanness should be made on shipment as delivered and frequent laboratory tests are recommended.

The different aggregates should be kept clean and separate until placed in the mixer. When aggregates are placed directly on the subgrade care must be exercised by the shovelers so that earth from the subgrade is not taken up with the aggregate.

Mixed aggregates such as bank-run gravel or crusher-run stone should not be used. Artificially prepared mixtures should not be allowed, since they will not be uniformly graded after handling, even if well graded when mixed.

Under rigid laboratory control it is possible to vary the proportions of aggregates and cement so that a strong concrete is obtained with materials not well graded. For the usual mix of fixed proportions, however, it is very important that fine aggregate be well graded with the coarser particles predominating, and that coarse aggregate be made up principally of the larger particles. Absence of the finer material in coarse aggregate is not detrimental; rather it is to be desired.

4. **Fine Aggregate.** Cleanness of sand is essential for good concrete. By cleanness is meant freedom from clay, loam, silt, or organic material. Organic material is especially harmful; its presence often cannot be detected by inspection. Sand should consist of quartzite grains or other equally hard material; particles of mica and feldspar are injurious and are to be avoided. Where screenings are available and sand is of higher cost, a mixture of screenings and sand, meeting the test, may be used. Fine sand can often be made suitable by the addition of screenings.

Where stone screenings are used, freedom from dust must be insisted upon, as dust makes difficult proper mixing and will reduce the strength of concrete, unless the time of mixing is much increased.

Field tests for grading should be made with a nest of standard sieves. Volumetric tests for silt determination are recommended, in which sand and water are shaken together in a graduated glass cylinder. The depth of the deposit on top of the sand is a measure of the foreign material present.

Detection of organic impurities of a humus nature in sand (this includes practically all organic material found in natural sands) has been made easy by the recent development of the colorimetric test whereby the presence of these impurities can be detected in the field within 24 hours after the sand is delivered on the job.

(See recommendations under Laboratory Control.)

5. **Coarse Aggregate.** Crushed stone should be tough, fairly hard and free from dirt. There is no advantage in using coarse aggregate decidedly harder than the mortar. Limestone with a French coefficient of wear as low as seven has been used successfully on one-course pavements. Brittleness is a quality to be avoided.

Where pebbles are to be used, attention should be directed toward detecting the presence of soft, flat or elongated particles. Aggregate containing such material should be rejected. Coarse aggregate containing particles up to three inches in diameter is being used satisfactorily in many localities.

6. **Quantities.** The quantities of materials for pavements of various thicknesses and widths are given in the table on p. 286.

7. **Water.** Ample supply of clean water, free from oil, acid, alkali or vegetable matter, is necessary. Water containing a large amount of organic material should not be used.

8. **Joint Filler.** Prepared strips of bituminous material and fiber matrix ¼ to ½ inch in thickness are recommended for expansion joints. The width of the joint filler should be at least ½ inch greater than the thickness of the pavement at any point. A joint filler which will not bend easily when concrete is deposited against it is desirable.

For contraction joints of the concealed type strips of sheet steel $\frac{1}{32}$ inch in thickness, 1 inch less in width than the least thickness of the pavement, are recommended. Two-ply tar paper has been used successfully for contraction joints. The paper should be brought to within ½ inch of the pavement surface.

9. **Protection Plates.** Joint protection plates are not recommended.

10. **Reinforcement.** A coating of light rust on the reinforcement will not be detrimental to satisfactory results, but no excessive rust, paint, or other coatings should be present to interfere with proper bond. Care should be exercised to see that the reinforcement is so stored prior to use, that it is not coated with mud or clay when placed in the pavement. Reinforcement left on a job when contract is not completed at the end of the season should be collected and stored so that it will be protected from the elements. Wire mesh, expanded metal or rods may be used.

132. Design.

11. **Cross Sections.** General design for cross sections of concrete roads are illustrated in Fig. 157, which shows sections for single- and double-track roads under varying typical conditions.

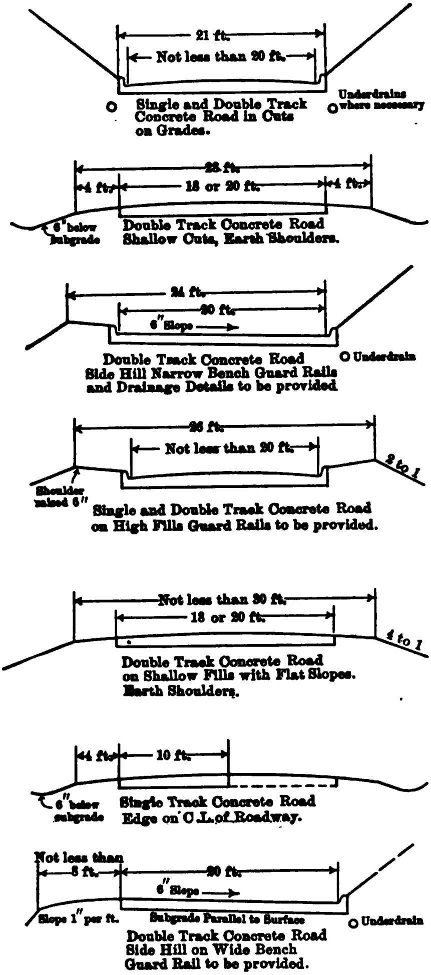

21 ft.
Not less than 20 ft.
Single and Double Track Concrete Road in Cuts on Grades.
Underdrains where necessary
28 ft.
4 ft.
18 or 20 ft.
4 ft.
6" below Subgrade
Double Track Concrete Road Shallow Cuts, Earth Shoulders.
24 ft.
20 ft.
6" Slope
Double Track Concrete Road Side Hill Narrow Bench Guard Rails and Drainage Details to be provided
Underdrain
26 ft.
Not less than 20 ft.
2 to 1
Shoulder raised 6"
Single and Double Track Concrete Road on High Fills Guard Rails to be provided.
Not less than 30 ft.
18 or 20 ft.
4 to 1
Double Track Concrete Road on Shallow Fills with Flat Slopes. Earth Shoulders.
4 ft.
10 ft.
6" below subgrade
Single Track Concrete Road Edge on C.L. of Roadway.
Not less than 8 ft.
20 ft.
6" Slope
Slope 1" per ft.
Subgrade Parallel to Surface
Underdrain
Double Track Concrete Road Side Hill on Wide Bench Guard Rail to be provided.

FIG. 157. RECOMMENDED CROSS SECTIONS FOR CONCRETE ROADS.

12. **Width.** In the design of a road there are two essential dimensions — width and thickness — which must be determined and which are the chief factors controlling the cost per unit of length. As it is always the endeavor to make this cost as little as

possible, too many roads are made both too narrow and too thin.

As the thickness of the pavement is to a certain extent a function of the width, the width is the dimension to be first determined. Owing to the greatly increased weight of traffic and to the fact that a large proportion of the traffic on the main roads is self-propelled, it becomes necessary that the width of the paved portion of the road should be sufficient to make it unnecessary for any of the wheels of a vehicle to leave the pavement and run upon the soft side or shoulder. If the traffic is all in one direction, and not so heavy but that a single track will be sufficient to care for it, then the paved portion of the road need be no more than is required for a single vehicle. This is a condition, however, that is never experienced practically, although it is approached on a number of roads. It frequently happens that at a given time of day nearly all the traffic is in one direction, particularly the loaded vehicles, so that it is rare for two loaded vehicles to meet. If one vehicle must leave the paved portion of the road it will be the unloaded vehicle. These conditions, combined with the fact that there is so limited a mileage of improved roads in most sections of the country, together with the endeavor to build a road between certain points with half as much money as should be expended, have made it expedient, apparently, to construct many miles of single-track roads.

Experience has shown, however, that no sooner has a road been improved than the amount of traffic it carries is increased many fold. Scarcely a year passes before the community discovers that the road is too narrow. If it were possible to handle such matters in the most efficient way, it is doubtful whether there would be found public roads on which single-track construction could be justified.

Single-track roads, that is, those accommodating but one line of traffic, should be 10 feet wide, with one edge laid on the center of the right of way so that when converted into a two-track road the new portion may be added entirely at one side, bringing the completed two-track road in the center. For industrial pavements where pedestrian traffic is large, and not otherwise provided for, 12 feet in width is recommended.

A two-track road should be not less than 18 feet where a majority of the traffic is lighter vehicles, and 20 feet where a considerable portion of the traffic is truck traffic.

A three-track road should be not less than 27 feet and preferably 30 feet if truck traffic develops to the extent of using two lines at a time.

A four-track road should be not less than 36 feet, preferably 40 feet if a large portion of the traffic is truck traffic.

13. **Thickness.** Two general classes of traffic, light and heavy, should be provided for with corresponding difference in thickness of the pavements. A light traffic road is one which carries, or is expected to carry, few or no vehicles over six tons gross weight. Such roads should be not less than 6 inches thick at the edges and not less than 8 inches thick at the center for 18 and 20-foot roads.

For single-track roads thickness should not be less than six (6) inches. Where early widening to a double-track road is anticipated, it would be desirable to increase the thickness at the inside edge to not less than eight (8) inches, thus securing a flat subgrade.

For heavy traffic roads, those roads carrying a considerable number of vehicles exceeding six tons gross weight, and not exceeding 15 tons, pavements should be not less than 8 inches thick at the sides and 10 inches at the center for 18 and 20-foot widths. For other widths, the thickness should be as shown in adjoining table.

The following thicknesses with corresponding widths are recommended for light and heavy traffic roads respectively:

THICKNESS FOR LIGHT TRAFFIC ROADS AND STREETS

Width, feet	Sides, inches	Center, inches
10	6 (outside)	8 (inside)
18	6	8
27	6	9
36	6	9½

THICKNESS FOR HEAVY TRAFFIC ROADS AND STREETS

Width, feet	Sides, inches	Center, inches
20	8	10
30	8	11
40	8	12

14. **Crown.** The crown on concrete roads should be as flat as possible and need not exceed 1/100th of the width, except on single-

track one-slope roads, which should have a crown of 1/50th of the width. Somewhat less crown can be employed on roads laid with a finishing machine than on those otherwise finished, owing to superior mechanical perfection of surface obtained.

On alley construction the crown should be the reverse of that for streets; that is, it should have a dished crown so that the water will run down the middle of the alley. It is recommended that the dished crown for alleys should be 1/50th of the width of the alley and that the subgrade for the alley be dished in the same manner so that the thickness of the pavement at every point will be the same. This should not be less than 6 inches for alleys in residential districts and not less than 8 inches for alleys that will be subjected to loads in excess of 6 tons.

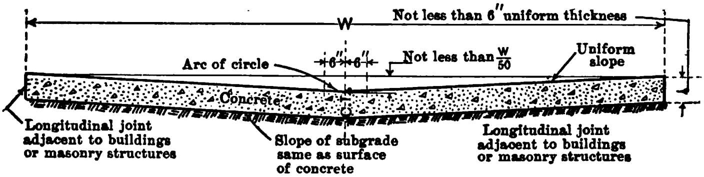

W
Not less than 6" uniform thickness
Arc of circle
6"
6"
Not less than $\frac{W}{50}$
Uniform slope
Concrete
Longitudinal joint adjacent to buildings or masonry structures
Slope of subgrade same as surface of concrete
Longitudinal joint adjacent to buildings or masonry structures

FIG. 158. RECOMMENDED CROSS SECTION FOR ONE-COURSE CONCRETE ALLEY.

"*w*" denotes width of pavement.

15. **Superelevation.** Curves should be superelevated to accomplish two purposes — to make them safe against skidding and to induce traffic to keep to the right side of the road and not tend to cut towards the inside as is the tendency on roads crowned in the ordinary manner around curves.

Unless otherwise indicated on the drawings, all curves shall be superelevated as follows:

Up to 250-ft. radius, ¾ in. per ft.; 250 to 800-ft. radius, ½ in. per. ft. On curves with a greater radius than 800 ft., the usual cross-section on level stretches shall be followed around the curves.

Unless otherwise indicated on the drawings, the grade of the center line is to be maintained and superelevation secured by raising the outside and depressing the inside edges of the pavement. In changing from the straight to the curved section, when the full superelevation is reached, the surface shall be without crown or dish.

It is recommended that embankments or other obstructions at curves should be so arranged as to afford around the curve a clear sight of not less than 500 feet.

In general, it is recommended that no highway be paved around a curve of less than 150 feet radius at the inside edge of the pavement.

16. **Widening Turns.** The shoulder on the outer edge of curves, particularly where the radius is less than 150 feet, should be widened as much as possible and the ditch on the outer side of the road placed as far away from the pavement edge as the right of way will permit. On the inside edge the shoulder should not be less than 4 feet wide.

It is recommended that on all curves of a radius less than 500 feet the paved portion be widened as follows:

Radius, feet	Extra width of pavement on inside of curve, feet	Radius, feet	Extra width of pavement on inside of curve, feet
50	8	300	4
75	7	400	3
100	6	500	2
200	5	...	..

This added area on the inside of the curve is a "lune." In order that the lune may fit the curve properly and not appear "broken backed," the curve of the inner edge must be a true arc, tangent to the edge of the straightaway sections, and, therefore, it must start before the P. C. is reached. The lune may easily be staked out on the ground with transit and tape by means of data derived from the radius and central angle of the center line curve.

In Fig. 159, R is the radius of inside edge of the pavement, if it is of uniform width around the curve. R' is the radius of the inside edge when the curve is widened by W.

$$X = R \operatorname{exsec} \frac{D}{2}$$

$$R' = \frac{X + W}{\operatorname{exsec} \frac{D}{2}}$$

$$T' = R' \tan \frac{D}{2} \cdot$$

The area of the lune *bcdf* in square yards

$$= \frac{\frac{\pi D}{360}\left((R)^2 - (R')^2\right) + (R + R')(T' - T)}{9}.$$

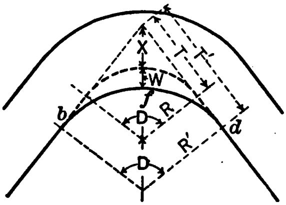


FIG. 159. EXAGGERATED DIAGRAM SHOWING WIDENING OF TURNS.

17. **Two-Course Construction.** It sometimes happens that the aggregate that is available is not suitable for the surface of a concrete road so that suitable material would have to be shipped in, usually at a considerably higher cost. Under these circumstances it is advisable to build a two-course pavement; the top course to be made of the higher-priced and better-grade aggregate. It is recommended for two-course work, under these circumstances, that the lower course be made of a mixture of 1 : 2½ : 4, using the local aggregate, and that the top course, which is to be laid immediately after the lower course has been spread and rolled, but not belt finished, be 2 inches in thickness and consist of a mixture of 1 : 1½ : 2½, using an aggregate not to exceed 1 inch in size.

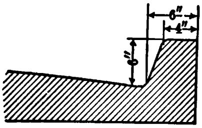


FIG. 160. INTEGRAL CURB FOR CONCRETE PAVEMENT.

18. **Integral Curb for Streets.** A concrete pavement and curb can be constructed at the same operation, the whole forming a unit. Such a curb is known as "integral curb" because it is a part of the pavement itself. It is suitable for boulevard, street, avenue, park drive, business thoroughfare, alley, driveway or road.

The form of curb which is recommended is one having a curved batter. It allows the full width of the street to be used, as it encourages drivers of cars to stop their machines close to the curb, there being no possibility that the tires or rims can be damaged. The natural tendency is for the driver to stay clear of the curb having a vertical face, by as much as 1 to 1½ feet, so as to avoid injury to the wheels of his machine. If cars on both sides of the street stop in this manner the effective width of the street may be reduced by as much as 3 feet. It must also be remembered that heavy wagons with steel tires sometimes back against the curb, sharp corners will be chipped off and the curb soon becomes unsightly. With the curb having a curved batter, however, there is no sharp corner and tires striking against it find no place where a piece can be easily chipped out.

The integral curb possesses features of distinct sanitary value when made with rounded corners. A curb which makes a sharp angle at its intersection with the pavement affords lodgment for dust and dirt. The sharp angle is difficult to clean. The curb with the rounded intersection offers no such collecting place and is much easier to keep free from rubbish. In fact, it is practically self-cleaning as the abrasive action of motor tires and wheels of other vehicles are effective in breaking up the deposits here, so that the first rain or flushing of the street will insure a clean gutter.

The construction of the integral curb has been made extremely simple by the development of efficient forms, one of which is shown in Fig. 161. There are two methods of using this, each having its advantages. Some contractors have preferred to put their forms into position and fill them with the concrete at the same time that the pavement is being placed. The advantage here is that there is no necessity for handling a separate part of the mix for the curb, enough concrete being deposited along the curb forms to fill them at the same time that the concrete is being placed for the pavement proper. The forms are filled from the top and the concrete is thoroughly spaded to insure uniformity.

When the concrete has hardened sufficiently the forms are removed and any stone pockets appearing on the surface are filled and the curb troweled over with a wooden float.

To secure a final finish that is smooth and uniform the curb is gone over with a whitewash or calcimine brush which has been dipped into a bucket of water and shaken out. The brush is used with a horizontal stroke and gives a perfect finish to the curb.

With the second method of building the integral curb it is placed after the pavement has been nearly finished. For this purpose it is necessary that the back form be in two parts; the upper part holding the curb mould is not placed until the surface of the pavement has been rolled as many times as necessary to remove the excess water and given the first belting. Then the upper half of the back form is placed and the mould for the curb attached and filled with concrete which is thoroughly spaded.

This method possesses the distinct advantage that the surplus water removed from the concrete in finishing will run off along the edge of the pavement of its own accord, whereas if the curb is placed with the pavement itself the excess water will flow to the gutter and must be removed. This is usually accomplished by using an ordinary street broom to brush the water along the gutter and off onto the subgrade.

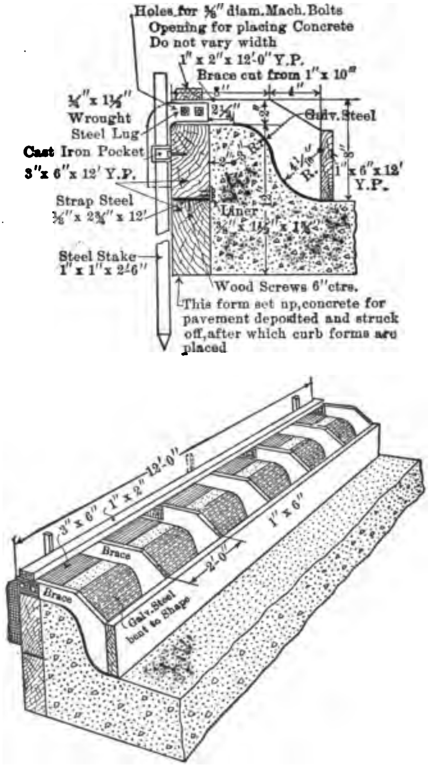

Holes for 5/8" diam. Mach. Bolts
Opening for placing Concrete
Do not vary width
1" x 2" x 12'-0" Y.P.
Brace cut from 1" x 10"
5"
4"
1/4" x 1 1/2" Wrought Steel Lug
Cast Iron Pocket
3" x 6" x 12' Y.P.
Strap Steel 3/8" x 2 3/4" x 12'
Steel Stake 1" x 1" x 2'-6"
2 1/4"
Galv. Steel
R.
4 1/2" R.
1" x 6" x 12' Y.P.
Liner 3/8" x 1 1/2" x 1 1/4"
Wood Screws 6" ctrs.
This form set up, concrete for pavement deposited and struck off, after which curb forms are placed
12'-0"
3" x 6"
1" x 2"
1" x 6"
Brace
Brace
2'-0"
Galv. Steel bent to Shape

FIG. 161. FORM FOR INTEGRAL CURB CONSTRUCTION.

It should also be noted that where a slight grade of several blocks is encountered it is well to build the road or pavement down grade so that the excess water removed in finishing will flow off onto the subgrade instead of back over the finished work.

A ½-in. joint in the curb shall be made at every joint in the pavement wherever it is provided that joints shall be constructed in the pavement. Joints shall extend entirely through the pavement and the curb and shall be in perfect alignment both transversely and vertically with the joint material.

Where the curbs are moulded to shape by the use of forms already described, the joint in the curb should be made with a tapered separator of oiled wood ½ inch thick at the top and cut to the exact section of the curb. This is held rigidly in place by a long hairpin while the material is being deposited in the forms. After the concrete is sufficiently hardened the curb forms are removed and the curb finished. The separator is tapped lightly until loosened and then withdrawn about ½ inch. The edges of the curb at the joint should be touched up with a pointing trowel to break the sharpness. The separator is then removed, care being taken not to break the side walls of the curb, and the joint is left open, no filler being used. (See Fig. 162.)

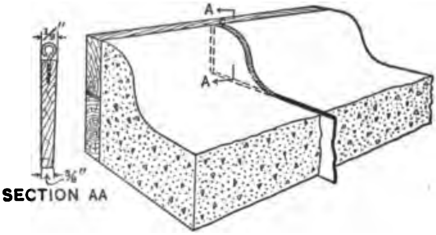


FIG. 162. SEPARATOR FOR INTEGRAL CURB.

133. Grading and Drainage.

19. **Grading.** In general, the requirements for grading of concrete roads are not essentially different from those pertaining to roads of other types of construction, so that there is little to be suggested for recommended practice that is essentially peculiar to concrete roads.

One point may well be emphasized, which is the profile to be established at railroad crossings. When it is not practicable to effect a separation of grades, grade crossings can be made much safer than otherwise if care is taken to have the road surface for a distance of at least 50 feet on either side of the railroad track at the same elevation as the top of the rails. (See Fig. 163.)

Similarly on approaches to bridges it is desirable that the grade of the road, for at least 50 feet, at each side of the bridge, shall be at the same elevation as the bridge floor.

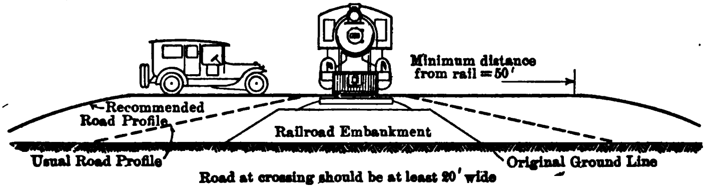


FIG. 163. RECOMMENDED PROFILE FOR RAILROAD CROSSINGS.

20. **Drainage.** The general features of road drainage are divided between surface and subdrainage. The requisites for surface drainage are a proper crown, slope of the shoulders to the gutters, and outlets for the water from the gutters through culverts and small bridges. Subdrainage is effected usually by laying a tile drain and backfilling the trench in which the drain is laid with rock, gravel or other porous material.

The essential point to keep in mind in draining a concrete road is to secure as nearly a uniform condition of subgrade as possible. This may be either a wet or dry condition. Thus over swampy ground it is practical to lay a concrete road without placing as high a fill as is necessary with macadam types of construction in order to secure for the macadam a dry roadbed.

Under these conditions, especially if the ground is very unstable, extra reinforcement should be used, placed near the bottom of the slab. Such reinforcement may consist of half-inch bars running both transversely and longitudinally, spaced 18 inches on center; the concrete slab should be not less than 8 inches in thickness.

A frequent source of considerable trouble may be pointed out. It is not uncommon on hills to find the character of the soil at the top considerably more porous and open than part way down the hill. And it will be noticed, wherever the more porous soil joins the closer textured soil, there will be an accumulation of water flowing along this seam. Where this seam intersects the roadbed there will, in wet seasons, always be found a seepy place. It will be necessary in such places, if trouble is to be avoided, that underdrainage be provided, which will reach into the porous soil sufficiently to intercept the water which it carries so it will not be deflected towards the surface of the road along the juncture of the more open with the denser soil. Unless there are indications which show clearly that in such situations the water is coming from one side of the road, the drain should extend under the center of the road from the porous soil and then split in two parts and discharge at each side further down the hill, running as a subdrain just under each edge of the pavement after the clay soil is reached.

Particularly in flat country, shoulder drains should always be provided when the concrete is laid on clay subsoil. These shoulder drains are cut through the shoulder for the width of a shovel from the subgrade to the bottom of the gutter. They should be cut at an angle of about 45° in the direction of the road and filled with broken stone to within 3 inches of the surface and then covered with material of which the shoulders are made. Shoulder drains should be put in at intervals of 50 feet on each side of the road.

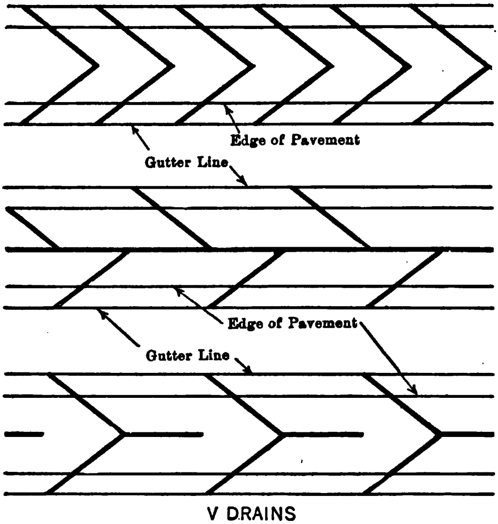


FIG. 164. INSTALLATION OF DRAINS.
The steeper the grade the greater the angle of the V.

On sections of the road where deep cuts have been made through clay soil, cross ditches 18 inches deep and about 1 foot in width should be placed under the surface of the road, starting at the center line, and thence at an angle of about 45° to the flow line of each gutter, the ditches to be filled with crushed stone or gravel. These ditches make a V with the point of the V at the center line, the angle of the V depending upon the slope of the hill. They should be put in at intervals of 75 to 100 feet. The first one should be just above the cut and the last one at the end of the cut.

134. Organization and Equipment.

21. **Two-Bag Batch Work.** The organization of the concreting crew is dependent in a large measure upon the varying conditions that are met with on every job.

A two-sack batch mixture is a convenient and economical size to operate for most pavement work, the width of which is not more than 20 feet. Many contractors prefer the three-sack mixer which permits greater yardage per day and usually assures a longer time in the mixer. The following diagram shows the division of labor for a crew for average standard equipment.

It will be noted that on some jobs some of these men can be eliminated. For instance, subgrading under the boom is not needed if proper attention has been given to the subgrade when first constructed.

ORGANIZATION OF CREW FOR CONCRETE PAVEMENT CONSTRUCTION — TWO-BAG BATCH

Based on widths up to 20 ft.; one-course, 1 : 2 : 3; boom and bucket delivery.

Contractor or Superintendent	Foreman (1)	Forms	Form Setter	(1)	
			Helper	(1)	
		Mixing and Placing	Shovelers and Wheelers	(5)	Circulating system, 4 wheelers; 1 shoveler.
			Cement Handlers	(3)	1 handling cement; 1 handling bags; 1 bundling sacks and handling.
			Engineer of Mixer	(1)	
			Fireman	(1)	Also sprinkles subgrade.
			Batch Operator	(1)	Not needed for standard equipment.
			Subgrader	(1)	For subgrading under boom, unnecessary on some jobs.
			Concrete Distributors	(2)	
			Water Boy	(1)	
			Reinforcing and Joint Installers	(2)	
		Finishing	Strikeboard Operators. Tampers Rollers and Belters	(4)	2 on strikeboards, 2 on roller and belts.
		Curing and Protection	Shovelers	(2)	2 shovelers cover as much of pavement as has hardened sufficiently, leaving what is too green for gang to cover next morning; also keep earth covering of pavement wet. Entire crew covers remainder of pavement each morning before beginning concreting.

ORGANIZATION OF CREW FOR CONCRETE PAVEMENT CONSTRUCTION — THREE-BAG BATCH

Based on width up to 20 ft.; one-course, 1 : 2 : 3; boom and bucket delivery.

Contractor or Superintendent	Foreman (1)	Forms	Form Setter	(1)	
			Helper	(1)	
		Mixing and Placing	Shovelers and Wheelers	(10)	1 gang, 5 shovelers; 1 gang, 5 wheelers; wheelers and shovelers may alternate or not.
			Cement handlers	(3)	1 handling cement, 1 handling bags from piles, 1 bundling sacks and handling.
			Engineer of Mixer	(1)	
			Fireman	(1)	Also sprinkles subgrade.
			Batch Operator	(1)	
			Subgrader	(1)	For subgrading under boom; unnecessary on some jobs.
			Concrete Distributors	(2)	
			Water Boy	(1)	
			Reinforcing and Joint Installers	(2)	
		Finishing	Strikeboard Operators Tampers Rollers and Belters	(4)	2 on strikeboards, 2 on roller and belts.
		Curing and Protection	Shovelers	(2)	2 shovelers cover as much of pavement as has hardened sufficiently, leaving what is too green for gang to cover next morning; also keep earth covering of pavement wet. Entire crew covers remainder of pavement each morning before beginning concreting.

ORGANIZATION OF CREW FOR CONCRETE PAVEMENT CONSTRUCTION — THREE-BAG BATCH

Based on width of 20 to 40 ft.; two-course, bottom 1 : 2½ : 4; integral curb; boom and bucket delivery.

Contractor or Superintendent	Foreman (1)	Forms	Form Setter	(1)	
			Helper	(1)	
		Mixing and Placing	Shovelers and Wheelers	(14)	Based on 2 gangs, one up and one loading.
			Cement Handlers	(4)	1 handling cement in skip, 2 handling bags from wagons and piles, 1 bundling sacks.
			Engineer of Mixer	(1)	
			Fireman	(1)	Also sprinkles subgrade.
			Batch Operator	(1)	
			Subgrader	(1)	For subgrading under boom, unnecessary on some jobs.
			Concrete Distributors	(2)	3 needed on 40 ft. streets.
			Reinforcing and Joint Installers	(2)	
			Water Boy	(1)	
		Finishing	Working Foreman	(1)	Also rolls and belts.
			Luter	(1)	
			Finishers' Helpers	(2)	Assist with curb work and rolling and belting.
		Curing and Protection	Shovelers	(2)	2 shovelers cover as much of pavement as has hardened sufficiently, leaving what is too green for gang to cover next morning; also keep earth covering of pavement wet. Entire crew covers remainder of pavement each morning before beginning concreting.

The equipment needed for two-bag batch operation is as follows:

700 lineal feet forms.
18 shovels.
8 wheelbarrows.
1 2-bag batch mixer.
1 roller with handle or ropes.
1 1-inch radius edger.
2 belts.
250 feet hose.
2 wooden floats.
1 strikeboard.
1 cross-section header board.
1 heavy wire cutter for reinforcing.
2 small hand nippers for opening sacks.
water pipe.
stakes.
sledge.

22. **Three-Bag Batch Work.** The typical organization of a crew for pavement work where the width is from 20 to 40 feet, two-course construction with integral curb based on a mix of 1 : 2½ : 4

for the first course, using standard equipment and boom and bucket delivery is shown on p. 258.

The equipment needed for a three-bag batch operation for work up to 20 feet is as follows:

1300 lineal feet forms.
20 shovels.
12 wheelbarrows.
1 3-bag mixer.
1 roller.
1 1-inch radius edger.
2 belts.
1 heavy wire cutter for reinforcing.
2 small hand nippers for opening sacks.
1 cross-section header board or joint installer.
water pipe.
350 feet hose.
stakes.
sledge.

The equipment needed for a three-bag batch operation for pavement construction 20 to 40 feet wide is as follows:

500 lineal feet forms.
300 lineal feet curb forms.
24 shovels.
18 wheelbarrows.
1 batch mixer.
1 heavy wire cutter for reinforcing.
2 small hand nippers for opening sacks.
1 split float.
1 split roller with ropes.
1 to 3 metal hand trowels.
1 cross-section header board or joint installer.
1 bridge.
1 lute.
1 set of 3 T's or stakes for sighting.
2 wooden hand floats.
1 long-handled float.
2 belts.
350 feet hose.
water pipe.
stakes.
sledge.

135. Handling and Hauling Materials.

23. **Unloading Yard.** Sufficient space is needed for bins, stock piles and cement storehouse in unloading yards where materials are

shipped in by rail. With uncertain transportation facilities, storing material at the siding is very desirable. If an industrial railway is used for hauling, a more extensive yard is necessary than with teams or truck hauling. For profitable operation an industrial railway should be in use constantly. A crane, derrick with clamshell bucket, bucket conveyor, or other power unloading device should be provided. Equipment that can be easily arranged about the yard is much preferred to stationary apparatus.

24. **Hauling Equipment.** Horse-drawn dump wagons, motor trucks, tractors and industrial railways are all used for hauling materials. For short distances over bad roads wagons may be most economical.

Trucks are coming into wide use and, where the roads over which they operate are in fairly good condition, are to be preferred to team hauling. Three-ton capacity trucks, capable of good speed, are usually more efficient than the larger size when used over the average unimproved road or pavement subgrade. The smaller trucks do not cut up the subgrade so badly and are easier to turn in cramped quarters than the larger machines. Industrial railways are adapted for use where the job is large, the average haul several miles, and unloading facilities ample. The investment is high and the equipment, therefore, must be kept in constant use for economic operation. Hauling is largely independent of weather conditions, but grades limit the speed and capacity of trains where slopes steeper than 4 per cent are encountered. Geared locomotives are ordinarily used where grades exceed 4 per cent; a locomotive of this type is much slower than a direct-acting locomotive. One great advantage of the industrial railway equipment lies in the fact that the subgrade is not cut up by hauling over it.

Materials may be dumped direct into the mixer from cars when the hauling is done over industrial railway. This method is recommended because labor is saved, larger mixers may be used, aggregates are kept clean, and material is not wasted on the subgrade. Where this plan is followed it is absolutely necessary that a continuous supply of materials be delivered to the mixer; sufficient equipment under proper supervision should be provided to make that certain. Good track construction and maintenance are of great importance.

One and one-half yard dump cars of 24-inch gauge are commonly made use of on industrial railways. The light 32-inch steel ties frequently found on built-up track sections are unsatisfactory, as longer ties are needed. Wooden ties have been used successfully, but steel ties in built-up sections are more convenient than separate ties and rails.

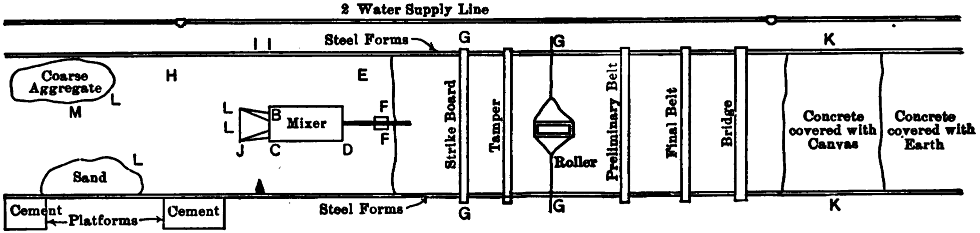


FIG. 165. ORGANIZATION FOR 1-COURSE PAVEMENT CONSTRUCTION, USING 2-BAG MIXER.

1 *A* Foreman
1 *B* Engineer of mixer
1 *C* Fireman
1 *D* Batch operator
1 *E* Subgrader
2 *F* Concrete distributers
4 *G* Strike board operators, tampers, rollers and belters
1 *H* Water boy
2 *I* Form setters
3 *J* Cement handlers
2 *K* Laborers to cover pavement with earth and keep covering wet
4 *L* Wheelers
1 *M* Shoveler assists stone wheelers to load

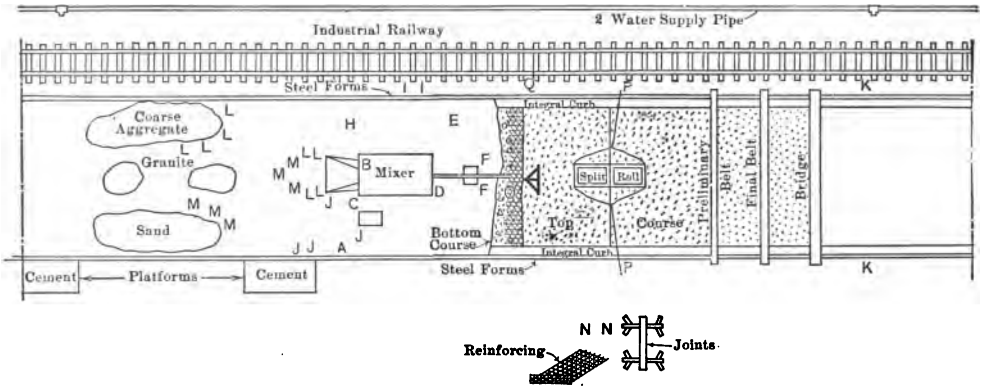


FIG. 166. ORGANIZATION FOR 2-COURSE PAVEMENT CONSTRUCTION USING 3-BAG MIXER.

1 *A* Foreman
1 *B* Engineer of mixer
1 *C* Fireman
1 *D* Batch operator
1 *E* Subgrader
2 *F* Concrete distributers
1 *H* Water boy
2 *I* Form setters
4 *J* Cement handlers
2 *K* Laborers to cover pavement with earth and keep covering wet
8 *L* Stone wheelers
6 *M* Sand wheelers
2 *N* Joint and reinforcing installers
1 *O* Lute
2 *P* Finishers' helpers
1 *Q* Working finishing foreman

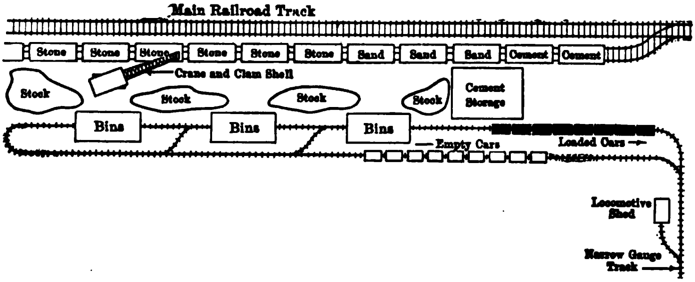


FIG. 167. PLAN OF UNLOADING YARD.

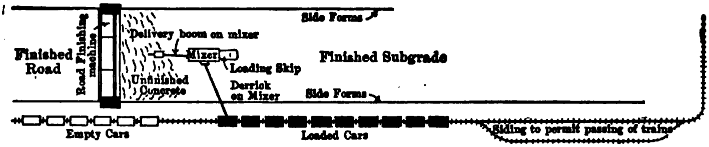


FIG. 168. TRACK ARRANGEMENT AND PLAN OF CONCRETE PLANT WHEN TRACK IS ON SHOULDER.

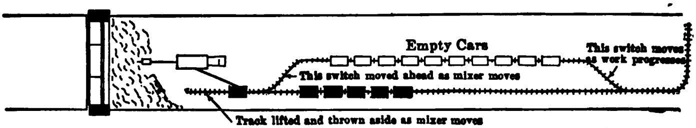

Empty Cars
This switch moves as work progresses
This switch moved ahead as mixer moves
Track lifted and thrown aside as mixer moves

FIG. 169. TRACK ARRANGEMENT AND PLAN OF CONCRETE PLANT WHEN TRACK IS ON SUBGRADE.

25. Placing on Subgrade. The fine and the coarse aggregates should be piled on opposite sides of the subgrade if possible and kept separate. Care should be taken to place aggregates on the subgrade in the quantities needed so that unnecessary labor and time will not be required to wheel the materials long distances to the mixer. Ample storage on the road is desirable unless the aggregates are dumped directly into the mixer.

Cement should be piled on boards or racks and shelter provided for it in case of rain.

Coarse aggregate when delivered upon the subgrade by either motor truck or teams very often requires a re-gradation before being placed in the skip ready for hoisting. Primarily the need for this is due to the number of times the material is handled before it reaches the job, thus separating the smaller sizes from the larger. The readjustment to a better graded condition may be made by the manner in which the wheelbarrows are loaded. The attention of the inspector is required to get proper results when the necessity demands this practice. This will prevent an uneven stony surface which will not roll nor belt with satisfactory results.

26. **Water Supply.** An ample supply of suitable water is necessary for concrete pavement work. Possible sources are city mains, wells, springs, tile drains, streams, and lakes. If careful investigation of all available sources of water supply near the work does not reveal a sufficient quantity to insure plenty of water regardless of the weather, it may be economical to sink 6-inch wells. In some instances small reservoirs or stand-pipes have been constructed to furnish small storage and to equalize pressures.

The water supply system should be of such a type as to require little attention and should furnish the necessary amount of water at all times at as uniform a pressure as possible. A contractor in making bids in the spring, when streams are high, should make sure by inquiry among local residents as to the dry season flow before placing dependence on any stream for his water supply.

The size and type of the pumping plant depend upon the length and grade of pipe line and the size and condition of the pipe. Where a two-sack mix is used, the pipe line should be able to deliver at least 25 gallons of water per minute at a pressure of approximately 50 pounds per square inch at any point on the pipe line. With a four-sack mix, the line should be able to furnish at least 40 gallons per minute. A triple plunger pump, either belt or gear connected to a gasoline engine, has been used with success in such work. The small additional sum required for the purchase of a good pump is well spent.

If water is to be taken from a deep well, it will be necessary to use two pumps and a storage tank or reservoir — a deep well pump to raise the water from the well to the reservoir, and a pressure pump to force it through the pipe line from the reservoir. In order to avoid possible damage to the pumping system, due to water hammer caused by shutting off valves quickly and in order not to overload the pump, it is necessary to place a relief valve in the line just ahead of the pump, with a bypass discharging into the source of supply. This valve should be set to open when the pump pressure exceeds that needed. When the valve opens, it will discharge the water back into the source of supply without waste. The diameter of the pipe line should be not less than two inches.

In addition to the loss of head, due to friction, account must be taken of the grade of the pipe line, since sufficient pressure must be provided for at the pump to give the required amount of water at the highest point of the line. The pipe line capacity may be greatly reduced by the rusting of the pipe, by formation of deposits, or by inserting lengths of smaller pipe.

T's for supplying water to the mixer and for sprinkling should be placed in the pipe line at intervals of about 200 feet. It is advisable to insert at least five gate valves per mile in the pipe line and enough additional valves should be provided so that one may be placed on each T for a sufficient distance back of the mixer to allow sprinkling for the required length of time. Hose not less than 1½ inches in diameter should connect the pipe line with the mixer in order to insure the filling of the mixer tank while a batch is being mixed and dumped. In laying the pipe line, drain valves should be placed at all the low points in order that when not in use the water may be drained out and thus avoid splitting of the pipes due to freezing. Neglect of this detail has caused great losses to concrete road contractors.

The amount of water needed for curing alone is estimated at 25 to 30 gallons per square yard. Even greater amounts may be needed in hot summer weather. For mixing, not over 8 gallons per square yard (average thickness of pavement 7½ inches) should be needed and a smaller quantity should be used unless aggregates are very dry. In sprinkling the subgrade the amount required will vary, but an allowance of 1½ gallons per square yard for sand or ½ gallon per square yard for clay should be used in figuring the quantity of water needed.

26A. **Mixer Loader.** Machines to load the hopper are in use and it is recommended that by their use a saving in labor can be effected. Their use also insures capacity operation for large sized mixers.

136. Mixing and Placing Concrete.

27. **Time of Mixing.** Materials should be mixed for a full minute. In general it is to be recommended that mixers should be supplied with timing devices so as to insure that each batch will get the proper amount of mixing.

27A. **Consistency.** The materials shall be mixed to such consistency that a 6- by 12-inch cylinder form filled with the concrete as mixed shall have a slump upon removing the cylindrical form not to exceed 5 inches, unless the surface is to be machine finished, in which case the consistency shall be such that the slump, upon removing the cylindrical form, shall not exceed 2 inches.

28. **Measuring Materials.** It is recommended that wheelbarrows holding either 2 or 3 cubic feet be used. A 1-cubic-foot measuring box should be provided (Fig. 170) and capacity of all wheelbarrows checked before they are used.

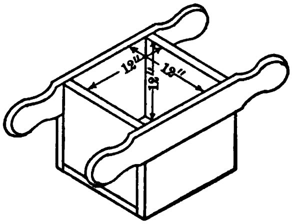


FIG. 170. ONE CUBIC FOOT MEASURING BOX.

Where the size or proportions of the batch do not permit the use of known capacity loads in the barrows, a paint mark should be inscribed on the inside of the pan of the barrow at a height as checked by the measured quantity of material required, determined with a measuring box when leveled.

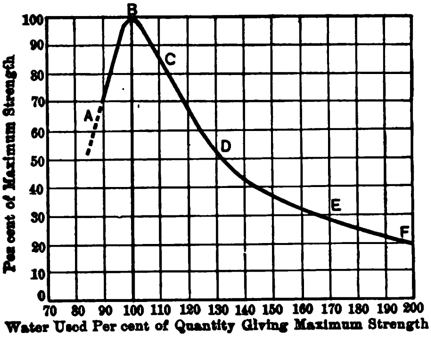


FIG. 171. CURVE SHOWING EFFECT OF WATER USED IN MIXING ON STRENGTH OF CONCRETE.

Point *B* represents maximum strength obtainable from mix. *C* to *D* is proper consistency for road work. From *D* to *F* strength decreases rapidly as water is increased.

29. **Side Forms.** Side forms which control the placing of concrete must be held rigidly in place. It is recommended that the

side forms be of steel and if the amount of work extends over a mile or two they will be found more economical than wood. Whatever the type of forms, it is recommended that stakes be driven upon which the forms are to rest; the tops of the stakes being at such an elevation that when the form is placed upon them the top of the form will be at the required elevation. For this purpose stakes of wood 2 by 2 by 12 inches in length are to be used. A stake should be placed near the end of each section of the form so as to insure true alignment where one section joins another and intermediate stakes placed at intervals of 4 or 5 feet. In addition to these stakes other stakes must be set sufficient to hold the forms to line. The joints in the side forms should not come opposite each other but should be staggered. (Fig. 172.)

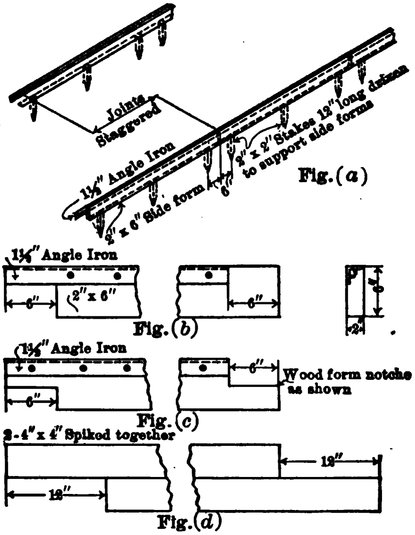


FIG. 172. FORMS SHOULD BE PLACED ON STAKES AS SHOWN IN (*a*) ABOVE.
(*b*), (*c*), and (*d*) show the form construction.

All mortar and earth shall be removed from the forms, and the side in contact with the concrete shall be given a wash of oil or soap before they are used.

30. Placing Concrete on Subgrade. The necessity for care in placing concrete from the mixer onto the subgrade has come to be more fully appreciated as more experience has been gained. If it happens for any cause that a batch of concrete as deposited in the road tends to have portions of the aggregate segregated it is of importance that the concrete shall be redistributed so that there shall be no segregation, particularly towards the surface. The drier the mixture the less tendency there is for this segregation, which furnishes an additional reason for care in the amount of water used in the mixer.

The subgrade should be firm and of as uniform density as possible. If it is dry or dusty it may be lightly sprinkled, but it should not be made wet. Concrete may be deposited from the mixer from an open chute or boom and bucket. If buckets are used which discharge by the opening of doors at the bottom, it is necessary to watch them carefully that no stone lodges in them to prevent their closing tightly. If the chute method is used the pitch of a chute should be steep enough to deliver concrete of a proper consistency. A chute of less angle may be used if a man with a shovel is kept at hand always to move the concrete along the chute.

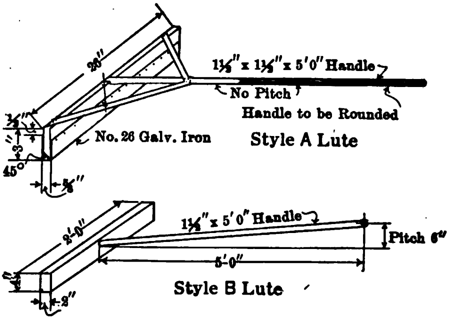


Fig. 173. Types of Lute.

On roads and streets not over 20 feet in width, it is practical to use a template cut to the proper crown and thus distribute the concrete over the entire pavement. If the strikeboard is made of wood it should be shod on the striking edge with a strip of steel. It is recommended that two strikeboards be used. The first one should have a 3 or 4-inch face, which is used as a tamper as well as to strike the concrete. (Fig. 179.)

On pavements wider than 20 feet it is recommended that concrete be distributed by luting. (See Fig. 173.) In this method a lute which resembles a toothless rake replaces the strikeboard.

The lute is operated so as to place the concrete approximately to the finished section. This is accomplished by placing steel pins across the road, the number depending upon the width; not less than three should be used and usually the number need not exceed eight. One pin should be placed on the center line and at least one on the quarter points. Rows of pins are placed across the road at intervals of 7 to 8 feet. These pins are set with their tops 2 inches higher than the surface of the concrete so that they may be readily seen and pulled out when the concrete has been placed around them. The pins are readily set in place by the use of **T**'s. A sight stick, on which the elevations for different points of the cross-section are marked by notches, is used to determine the elevation of each pin. The slight unevenness that is left in the surface of the pavement after it is luted is entirely removed by the use of the roller and belt described under "Finishing."

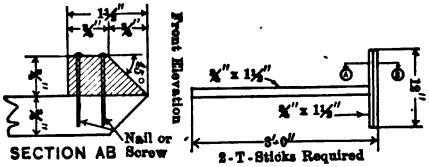


FIG. 174. T-STICK FOR SIGHTING IN POINTS.

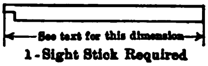


FIG. 175. DETAIL OF SIGHT STICK.

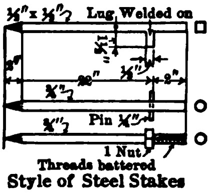


FIG. 176. STEEL STAKES USED TO MARK POINTS FOR LUTING.

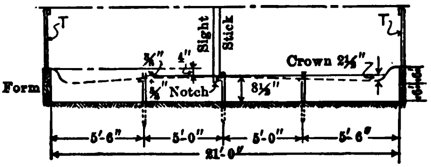


FIG. 177. METHOD OF SIGHTING IN POINTS WHEN LUTING METHOD IS USED TO OBTAIN PAVEMENT CONTOUR.

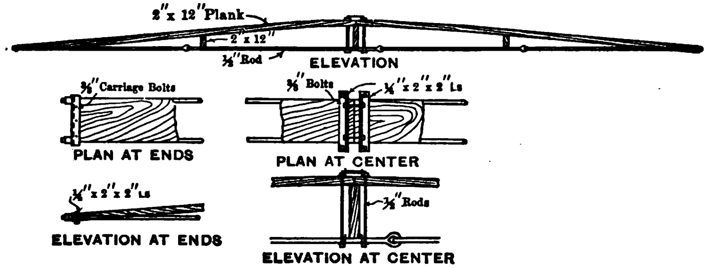


FIG. 178. BRIDGE FOR PAVEMENTS MORE THAN 20 FEET WIDE.

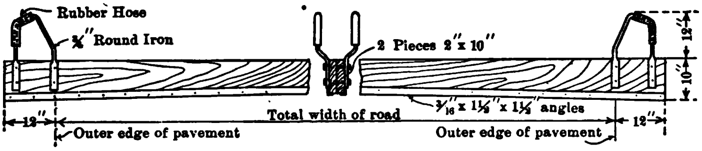


FIG. 179. DETAIL OF STRIKEBOARD.

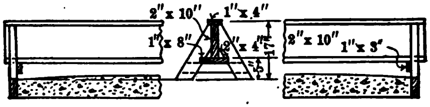


FIG. 180. BRIDGE FOR PAVEMENTS UP TO 20 FEET WIDE.

31. Placing in Cold Weather. The construction of concrete pavements during freezing weather is not recommended because of hazards and the added cost made necessary by the protection of the concrete.

It is sometimes necessary to finish up a job of concrete street or road paving which is nearly completed during a time when the temperature may drop below freezing and on such work caution should be taken to avoid any possibility of the concrete being damaged by frost.

Concrete should not be placed on a frozen subgrade. Methods to be followed in combating the injurious effects of cold weather may be grouped under the following headings:

(*A*) Application of artificial heat to materials or finished work, and means of preventing the dissipation of heat developed during the setting and hardening of the concrete. (Heating of water or aggregates; heating fresh concrete by steam lines; the use of covering, etc.)

(*B*) Use of chemical compounds which will lower freezing point of mixing water, or accelerate the setting and hardening of the cement.

Special care must be taken to avoid the use of lumps of frozen aggregate. On account of the frequent moving of equipment, heating of the aggregates is not always practicable in road work, although this can be done in other kinds of concrete construction.

If a road roller or other source of steam supply is available, the aggregate piles may be heated by inserting steam pipes carrying live steam. This heating will be greatly facilitated by covering the piles with canvas.

Valuable results can be obtained at little expense by heating the mixing water. This can best be accomplished by inserting an improvised steam coil in the water line near the mixer. The water coil may be heated by a wood or coal fire. It is not necessary that the water be extremely hot, as it will accomplish a useful purpose if this method serves to remove only the chill from the aggregate and impart some heat to the fresh concrete. Satisfactory heaters for this purpose are on the market.

The chemical reactions which accompany the setting and hardening of the concrete generate some heat, and where there are indications that the temperature will fall below freezing during the few hours following the placing of the concrete it is important that this heat be retained. This may be accomplished by placing a covering of canvas or other material over the newly-laid road in such a manner as to leave an air space above the concrete. Disturbance of the enclosed air should be prevented as much as possible by weighting the canvas with timbers, sand, or earth.

In the event of an extreme drop in temperature, pipe lines supplied with live steam may be carried under the canvas to protect the fresh concrete from freezing. If the concrete is partially hardened, protection may be provided by covering it with straw.

A 1-inch layer of sawdust, with a canvas over top, has been found very satisfactory where the temperature does not drop more than 3° or 4° below freezing. Hay or straw used as a covering, covered over with canvas, will also serve the same purpose. It is important, where this is used, that the material be lightly forked onto the road so as to retain as much air as possible, which is the heat-retaining medium.

Of the chemical compounds which have been used in cold-weather construction work, calcium chloride probably gives the best results. Calcium chloride possesses the property of lowering the freezing point of water and accelerating the setting of cement. Laboratory tests show that small quantities of calcium chloride do not cause an appreciable reduction in the strength of the concrete, nor corrosion of the reinforcing steel.

This compound is generally sold in crystal form and is readily soluble in water. If used in quantities of about 3 per cent by weight of the mixing water it will enable the concrete to be placed with the temperature slightly below freezing with little danger of injury.

It can best be added to the mix by making a solution having a concentration of 1½ pounds of calcium chloride per gallon of water. This solution may be kept in a barrel near the mixer and a gallon of it added for each sack of cement used. For the usual 1 : 2 : 3 mix this corresponds closely to 3 per cent of the total mixing water.

The use of this material will add about 3 cents per square yard to the cost of the concrete.

Attention is called to the fact that these special measures of heating aggregates, etc., should be adopted only after all ordinary precautions are in effect. The heating of the mixing water should not be counted upon to counteract the ill effects of dirty or poorly graded aggregate or an oversupply of water in the batch.

The use of chemical compounds should not be solely depended upon to prevent freezing as they should be used only in conjunction with the other methods for insuring good concrete.

The strength of concrete is greatly affected by the temperature during the time of setting, as shown by an investigation carried out by Prof. A. B. McDaniels at the University of Illinois.

The comparatively low strength of concrete exposed to cold weather increases the importance of taking precautions to exclude traffic for a longer period of time from concrete roads finished at lower temperatures.

137. Joints and Reinforcing.

32. **Types.** Joints are of two general types, the expansion joint, where space is left which is filled with a plastic material, and the contraction joint, which divides portions of the concrete without any appreciable space being left between.

33. **Expansion Joints.** Where expansion joints are used it is recommended that the space be not less than ¼ inch and not more than ¾ inch and that some prepared form of filler be used which can be handled readily and which is of sufficient stiffness to permit placing.

All expansion joints should extend entirely through the pavement and through the integral curb when that is constructed with the pavement.

34. **Contraction Joints.** If contraction joints are to be made at points other than where the work has stopped temporarily as at noontime or the end of a day, what is known as the concealed joint is recommended. This is constructed by placing a thin sheet of material, preferably metal, at the place where the joint is desired, the plate extending to within 1 inch or less of the surface, thus permitting the road to be finished with the same facility as though no joint had been provided.

Instead of a thin sheet of metal a thickness of tar paper has been successfully used, but unless the joint is to extend entirely through the pavement and be of the expansion type, no appreciable thickness of compressible material should be used in this construction.

35. **Joint Spacing.** Joints should be placed at regular intervals. The theory of expansion joint assumes that after the road is constructed the concrete slabs expand, due to increased temperature and moisture content. The expansion space is provided by the joint material. The tendency is to increase the spacing between joints and from 25 to 35 feet has been the usual practice. This is being increased to 50 feet, which spacing is recommended. But where concealed contraction joints are used it is recommended that they be spaced 30 feet.

36. **Installation of Joints.** For installing expansion joints a wooden bulkhead cut to the exact cross-section of the pavement should be used. For pavements up to 20 feet in width this may be cut from a single piece of 2-inch plank, while if the bulkhead is to be more than 20 feet in length it should be in two sections, each of these sections being made up of two thicknesses of 1-inch dressed lumber.

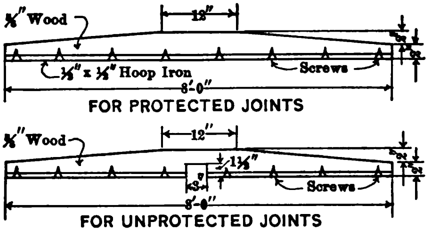
A cord is stretched between forms at the desired location of the joint at right angles to the center line of the pavement. Two by four stakes are then driven and the bulkhead placed against them. Care should be taken to see that the height of the bulkhead at the curbs or sides of the pavement conforms to the desired elevation. If the bulkhead is made in two parts, as on wide streets, it will be necessary also to set the middle of it so as to insure the proper elevation at this point.

The joint material is then placed against the bulkhead and pinned down with steel pins on which there is an outstanding lug. A few shovelfuls of concrete are thrown against it to keep it upright. Concrete is then deposited up to this joint and luted or struck to place. The mixer is then moved ahead and concreting continued for about 8 to 10 feet. Where a finishing machine is used the joint filler should not protrude above the surface.

The wooden stakes supporting the bulkhead are then removed and concrete worked under it as the bulkhead is lifted from one end. After the bulkhead is removed the surface adjacent to the joint is brought to grade as established on the other side of the joint with a small amount of additional material.

It will be noted that as the bulkhead is cut to the exact cross-section of the pavement it furnishes a precise mark or level for luting.

To insure that the concrete on both sides of the joint is at the elevation corresponding to the adjacent surface of the pavement a wooden straight-edge, which can be made of ⅝-inch stock, 5 inches wide and about 8 feet long, shod on the under side with $\frac{1}{16}$-inch strap iron, should be worked at right angles to the joint, using a sawing motion of 2 or 3 inches. A notch is necessary at the center of this straight-edge to provide for the joint material which projects above the surface of the pavement. (Fig. 181.)



FOR PROTECTED JOINTS

FOR UNPROTECTED JOINTS

FIG. 181. STRAIGHT-EDGE FOR SECURING SMOOTH RIDING JOINTS.

By beginning at the center of the slab and working toward each edge the surplus concrete left by the strikeboard is swept off, producing a uniform surface on both sides of the joint.

This work should be done from the finisher's bridge and should follow up the strikeboard immediately after it has passed the joint.

A split-float should also be used to secure the final finish at the unprotected joints. (Fig. 182.)

Before the pavement is opened for traffic, the joint material which extends above the pavement should be trimmed so that not more than ⅜ inch of it is above the surface. By riveting cleats on the bottom of a shovel a tool is formed which accomplishes this with the minimum amount of labor. The shovel is pushed against the joint material, trimming it to the height required. (See original report, Fig. 29.)

Around catch basins, manholes, inlets, telegraph poles, and other structures that may protrude through the surface of a pavement it is recommended that ¼ to ½ inch expansion joint should be made. The filler for the joint should be of such material that it will remain in place when put around the catch basin or other structure protruding through the pavement and should extend about ½ inch above the surface. The filler material is first put into position and then the concrete placed about it.

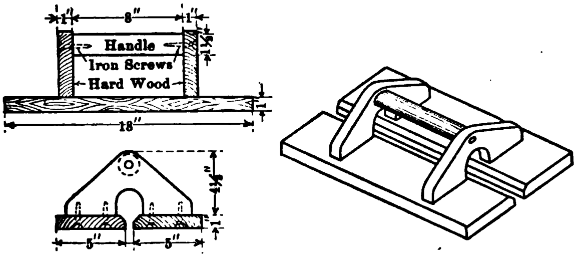


FIG. 182. SPLIT FLOAT FOR FINISHING AT JOINTS.

37. Placing Reinforcement. For pavement reinforcement wire mesh or expanded metal with an effective weight of approximately 25 pounds per 100 square feet is recommended.

The reinforcing should be placed not less than 2 inches from the finished surface of the pavement and should extend to within 2 inches of all joints, but not across them. Adjacent widths of the fabric should be lapped not less than 4 inches when the lap is made perpendicular to the center line of the pavement and not less than 1 foot when the lap is parallel to the center line.

The effective areas of the reinforcing members at right angles to each other may vary between 1 : 1 and 6 : 1. Reinforcement should be placed so that the effective sectional area measured parallel to the center line of the pavement is at least as great as that measured at right angles to the center line. It is recommended that the former area be from three to five times the latter since the reinforcement will then offer greater resistance to the formation of longitudinal cracks.

It is essential that reinforcing be free from excessive rust, paint, or scale so that it will obtain a firm bond with the concrete.

As wire mesh is delivered in rolls, it must be straightened before placing on the base course, to insure complete covering by two inches of wearing-course concrete. As the weight of reinforcement increases, this is a more important matter, and special apparatus must be provided to do the work. For this purpose the American Steel & Wire Company has devised a straightening machine. The machine is set up on a wooden frame of sufficient height so that a roller will support the roll of reinforcement clear of the ground. A team hitched to the forward end of the roll pulls the mesh through the straightening machine. The mesh drops to the ground and is cut to required lengths. The contractor, on whose work the photo shown was taken, also hauls six to eight lengths of reinforcement by team to the point on the work where they are to be used. The usual method is to cut a number of lengths of the reinforcing material, place them in one pile on the roadbed and iron them straight with a steam roller.

38. **Circumferential Reinforcing.** This method of reinforcing concrete roads is comparatively new, but has been used successfully in a few pieces of work. It consists in laying around the edge of the slabs a single steel bar ¾ inch round or ⅝ inch square. The object of concentrating the reinforcement at the edges is to place it where it has been observed that cracks usually originate. Fig. 183 and Table XXIII show the method of placing the rods and the amount of steel required for each slab on 18-, 20-, and 24-foot pavements with varying joint spacing.

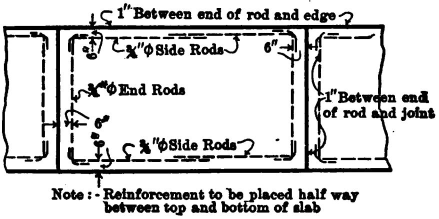

1" Between end of rod and edge
6"
¾"ϕ Side Rods
6"
¾"ϕ End Rods
1" Between end of rod and joint
6"
6"
¾"ϕ Side Rods
Note:- Reinforcement to be placed half way between top and bottom of slab

FIG. 183. METHOD OF PLACING CIRCUMFERENTIAL REINFORCING.

Reinforcement may consist of ¾-inch round or ⅝-inch square bars placed in the following manner: Where joints are made either of the expansion or contraction type, a bar shall be laid transversely across the road parallel with the joints and not less than 6 inches or more than 8 inches from either side of the joint placed within 2 inches of the top of the slab. The ends of the rods at the corners shall be bent at right angles 6 inches from the end. Longitudinal rods shall be placed not less than 6 inches or more than 8 inches from the sides of the slab and laid within 2 inches of the top.

If the convenience requires that more than one length of rod shall be used in a given slab, they shall be lapped at least 10 inches. Additional transverse rods shall be used as may be indicated on the plans.

If the pavement is constructed without joints, either expansion or contraction, longitudinal rods shall be laid as above described, and transverse rods placed as shown upon the plans.

For pavements 30 feet or over in width, circumferential reinforcement is to be laid in addition to mesh reinforcement, the rods to be placed as here provided or as may otherwise be shown upon the drawings.

138. Finishing.

39. **Machine Finish.** Two methods of finishing are used, machine finish and hand finish. Machines for finishing concrete surfaces are recommended. The concrete should have a consistency as measured by the cylinder test of not greater than a 2-inch slump. Machines shall be so constructed and operated that they will strike off and thoroughly tamp the concrete, and move over the same area repeatedly, giving a compact and finished surface which shall be true to grade and crowned absolutely free from porous places, and the surface in general shall have a uniform appearance. A machine requiring concrete of a thin consistency for operation is not recommended.

40. **Roller and Belt Method.** The roller and belt method of finishing is recommended where machines are not used. Concrete shall be brought to a proper contour in the following manner:

On roads and streets not over 20 feet in width, and where a finishing machine is not used, the concrete shall first be tamped, then struck off with a template, shaped to the proper crown, the striking edge of which shall be of steel. The template is to be moved continuously over the surface in a sliding motion. Any inequalities or holes shall be filled immediately with concrete from the last batch deposited.

On pavements wider than 20 feet, concrete may be distributed by a lute or toothless rake so operated as to place the concrete to the finished section. Where luting is used steel pins shall be driven, with their tops set accurately to elevation to the finished surface; pins to be placed not over 8 feet apart, measured either transversely or longitudinally of the road and in no instance to have less than three pins across the road, one of which shall be at the center and one each at the quarter points.

Concrete adjoining transverse joints shall be dense in character and shall be finished with a wood float which is divided through the center so as to permit finishing on both sides of the joint at the same time. When sure that the concrete on both sides of the joint is at the same elevation extending to the adjacent surface of the pavement, it shall be tested by means of a wooden straight-edge not less than 8 feet long. It shall be notched in the center and cut so that the joint material will not interfere with the straight-edge coming in contact with the concrete. This straight-edge, which should be shod with a strip of steel, shall be used as a strikeboard or template to secure proper contour of the surface of the concrete adjacent to all joints.

As soon as possible after the concrete has been struck off it shall be rolled with an approved metal roller, having a smooth, even surface, approximately 6 feet in length, not less than 8 inches nor more than 12 inches in diameter, and weighing approximately 100 pounds. (Figs. 184–185.) On pavements less than 20 feet in width, the roller may be operated with a handle, which shall be at least 2 feet longer than the width of the pavement, and all rolling shall be done from one side of the slab. On pavements 20 feet and more in width, the roller shall be provided with two bails, to which ropes shall be attached, and the roller pulled across the pavement. The roller shall be operated in such a manner that it advances along the pavement about 2 feet for each time across. The roller shall pass from one edge of the pavement to the other, care being taken not to run the roller over the side forms so that earth or other foreign material will adhere to it. After the roller has covered a given area in the manner described, the same area shall be similarly covered by the roller not less than three times at intervals of fifteen to forty

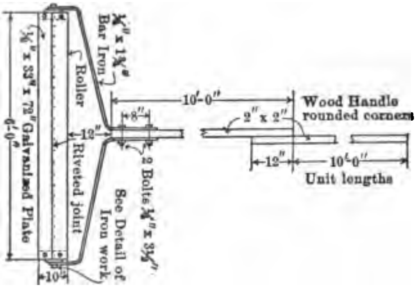


FIG. 184. DETAIL OF ROLLER FOR FINISHING.

minutes, and as many times additional as may be necessary to remove excess water.

After the rolling has been completed the pavement shall be finished by two applications of a belt made of canvas or rubber belting, not less than 6 inches wide and not less than 2 feet longer than the width of the pavement. The belt shall be applied with a combined cross-wise and longitudinal motion. For the first application vigorous strokes at least 12 inches long shall be used, and the longitudinal movement of the belt along the pavement shall be very slight. The second application of the belt shall be immediately after the water glaze or sheen disappears, and the stroke of the belt shall be not more than 4 inches and the longitudinal movement shall be much greater than for the first belting.

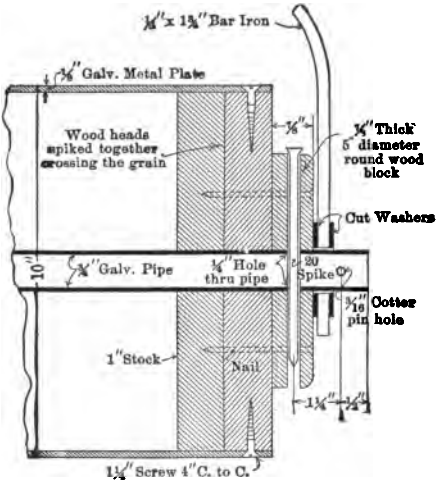


FIG. 185. LARGE SCALE DETAIL OF ROLLER FOR FINISHING.

The finished surface of the concrete shall not vary from a line parallel to the pavement center line more than $\frac{1}{4}$ inch in any 3-foot length when tested with a gage with which all variations can be measured accurately, and any allowable change in elevation shall be gradual.

At every point in any cross section of the pavement the finished surface of the concrete shall be convex upward.

When the belting has been completed the portion of the surface next to the forms should be smoothed if necessary with a wooden float and the edge of the pavement rounded to a radius of 1 inch with a suitable edging tool.

139. Curing.

41. **Earth Covering.** The method which has been used more than any other in curing concrete pavements is to keep them covered for at least ten days with a layer of not less than 2 inches of earth, which is kept moist by sprinkling. As soon as the concrete has been finished with the final belt it is covered with canvas to prevent rapid evaporation. As soon as it has hardened sufficiently to permit earth to be thrown on without damaging the surface, this is done and the earth sprinkled at regular intervals to insure a moist covering. After a period of 10 days this covering is removed, but the pavement is kept closed to traffic for at least four days more and in some cases 10 days to two weeks longer if the temperature is below 50° F. to insure thorough curing.

When the average temperature is below 50° F. it will usually be found desirable to omit the earth covering and sprinkle the pavement only when the concrete shows signs of drying out too rapidly. Except on days when the sun is unusually warm, sprinkling night and morning will be sufficient. Hardening shall be allowed to progress slowly and uniformly, but shall not be so much retarded that opening of the pavement to traffic in a reasonable length of time is prevented.

42. **Ponding.** Another method of curing concrete pavements, which has proved eminently satisfactory, is by keeping them covered with about 2 inches of water, which is retained by earth dams built across the pavement at frequent intervals. (See original Report, Fig. 33.)

After finishing the concrete, it shall be covered with canvas until it has hardened sufficiently to permit building earth dams across the pavement to be placed at the joints, where joints are used, and along the edges where no curb is built. The surface of the concrete is then to be covered with water to a minimum depth of 2 inches which shall remain upon the pavement for at least ten days, when the water shall be drawn off and the pavement left exposed for at least four days before it shall be opened to traffic, and in cool weather for such additional time as may be determined by the engineer. No traffic shall be permitted to use a pavement until all earth coverings have been completely removed. On portions of the pavement where the grade is such as to make ponding impracticable the surface shall be covered with earth for a depth of not less than 2 inches and kept wet for at least ten days.

Flooding is generally done in the evening when the water is not needed for the mixer, and it is kept at a minimum depth of 2 inches at the crown for at least 10 days.

After the pavement has cured sufficiently with the water covering, the dikes are broken and the water allowed to run off, leaving the surface clean.

In order to protect the pavement from traffic, it is necessary that suitable barricades be erected and, where it is necessary, detour signs shall be put up so as to cause traffic the least inconvenience possible.

(*Perform Job No. 107, Vol. II.*)

TABLE XXIII

MATERIAL REQUIRED FOR CIRCUMFERENTIAL REINFORCING

Quantities and Lengths of ¾-inch Round Rods* for 1 Concrete Slab

Distance between joints in feet	Width of road in feet								
	18 feet			20 feet			24 feet		
	Number and length of end pieces	Number and length of side pieces	Total weight of both per slab, pounds	Number and length of end pieces	Number and length of side pieces	Total weight of both per slab, pounds	Number and length of end pieces	Number and length of side pieces	Total weight of both per slab, pounds
	ft. in.	ft. in.		ft. in.	ft. in.		ft. in.	ft. in.	
25	2 18 0	2 25 0	129	2 20 0	2 25 0	135	2 24 0	2 25 0	147
35	2 18 0	2 35 0	159	2 20 0	2 35 0	165	2 24 0	2 35 0	177
40	2 18 0	4 21 0	180	2 20 0	4 21 0	186	2 24 0	4 21 0	198
50	2 18 0	4 26 0	210	2 20 0	4 26 0	216	2 24 0	4 26 0	228
75	2 18 0	6 26 6	293	2 20 0	6 26 6	299	2 24 0	6 26 6	311
100	2 18 0	8 26 6	372	2 20 0	8 26 6	378	2 24 0	8 26 6	390

* ⅝"☐ Bars may be substituted, reducing weights to 88½ per cent of those shown.

140. Maintenance.

Maintenance should be systematic and imperfections given immediate attention.

43. **Cracks and Joints.** The crack or joint should first be cleaned with a sharp hooked pick and stiff brush, care being taken to remove all loose particles. If the opening is too narrow to permit cleaning in this manner, it should be cleaned with an air jet from an automobile tire pump. After thorough cleaning, tar should be poured into the crack in sufficient quantity just to flush over the edges. The tar should then be covered with coarse dry sand. It will usually be found desirable to remove old joint material to a depth of ¼ to ½ inch below the surface of the concrete, so that new repair materials will have a good bond.

Care should be taken not to pour the tar in such quantities that an unsightly wide strip is made on the surface. By bending the spout of the tar pot so that a long, narrow opening is provided the tar can be poured in a very thin, narrow stream. It needs but a little attention to pour cracks so that a narrow ribbon of tar 1 to 2 inches in width is left.

44. **Tar.** Refined coal tar should be used, having a melting point (½ inch cube method in water) of about 100° F. The tar should be heated from 225° to 250° F. at the time of application and may be applied by means of a sprinkling can with spray nozzle removed.

45. **Surface Pockets.** A pocket in the surface, 1 to 3 inches in size, due to soft aggregates or the disintegration of a lump of clay, or a piece of coal or wood, should first be thoroughly cleaned. It should then be filled with hard, small aggregates, ranging in size from ¼ to ⅜ inch. Hot tar should then be poured into the opening until the tar is flush with the surface. Very coarse, dry sand should then be sprinkled on the tar immediately.

A cold mix of small stone and emulsified asphalt has been successfully used for this type of repair work.

46. **Slight Depressions.** If for any cause a slight depression has formed, it can be coated with tar, very coarse sand added, covered with tar, and the whole covered with sand and tamped into place.

47. **Replacements.** If it is necessary to cut a hole through the entire thickness of the concrete slab, gravel should be placed in the sub-base and thoroughly rammed, so as to form a compacted base on which the new concrete will rest. Where water has been allowed to stand in such a place, it should be compacted after the water has been removed and just before laying the concrete. Be-

fore placing the concrete the sides of the opening should be painted with a mixture of neat cement and water.

The consistency of the concrete should be sufficiently stiff to require considerable tamping to bring water to the surface so that it may be possible to ram it thoroughly into place. A small tamp, made of a 2 by 1-inch stick, 18 inches long, should be used to ram the concrete adjacent to the edges.

After the concrete is rammed into place it should be struck true to the surrounding surface. A repair made in this manner cannot be told from the old pavement after a few months' use.

A new patch should be kept moist for at least four or five days, and protected from traffic at least 10 days.

Equipment that has been found to work very satisfactorily and economically for the maintenance of concrete roads by the Illinois Division of Highways, Department of Public Works, is shown in the original report, Figs. 34–35.

141. Resurfacing Old Concrete Pavements.

Where an old concrete pavement is to be resurfaced, care must be taken to clean the pavement thoroughly. Grout of wet consistency should be thoroughly brushed over the old surface and every effort made to secure a bond between the two layers of concrete. In placing, finishing, and curing the new concrete the recommended practice for concrete pavements should be followed. Joints should be provided in the top layer directly over those in the pavement below. These can be made by placing wooden strips over the old joints when new concrete is placed. After the resurfacing has hardened sufficiently to allow the removal of these strips the space left is filled with tar or other joint filler.

The thickness of the resurfacing layer should not be less than 3 inches and should be mixed in the proportions of 1 : 1½ : 2½, using particles ¼ to 1 inch for the coarse aggregate. Steel reinforcement weighing at least 25 pounds per 100 square feet should be placed in the middle of the resurfacing layer.

If there are any holes in the surface of the old pavement these should be thoroughly brushed out and filled with 1 : 2 : 4 concrete before placing the top surface.

Where it is desired to widen the pavement in conjunction with the resurfacing, concrete of 1 : 2 : 4 mix should be placed along the edges of the slab to the width desired and of the thickness of the old slab. The edges of the slab should be thoroughly wetted to insure a bond.

This concrete should then be struck off to the surface of the old slab and allowed to cure for two days, during which period it should be kept wet. The resurfacing is then placed on the widened slab as previously outlined.

142. Machine Bases. The proportions of the concrete in machine bases can be safely placed at **1–2–3,** as for one course pavements. The important items in this work are the location of **anchor bolts** and the equal distribution of load. The location of anchor bolts should be determined from the details of the base of the machine to be set and a **template** and **form** should be made to set them accurately. Fig. 186 illustrates the template and form for a shaper base for this building. The rough concrete is cast to a level and smooth surface and the machine is set over the bolts after this has hardened for about six days. The machine is leveled accurately by the use of **steel wedges,** being brought to continuous even bearing by **floating a thin layer of cement grout** under all the accessible parts of the machine base.

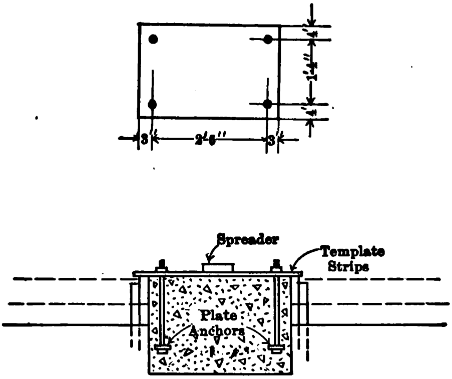


FIG. 186. SETTING ANCHOR BOLTS FOR MACHINES.

143. Wood Blocks. The laying of wood block pavements upon concrete slabs is accomplished by **bedding** and **leveling** them upon a sand cushion about **$1\frac{1}{2}$ inches thick.** The blocks are placed as close together as possible and then **floated with pitch** and **sanded.** The blocks used are **creosoted** to prevent decay. This floor is noiseless and smooth and is very desirable for such buildings as this.

144. Problems for Review

Prob. 144*a*. Check the values given in Table XXII for a 10- and 20-foot roadway.

Prob. 144*b*. Using the information given in Fig. 159 and that under Art. 132–16, calculate X, R', T', and the area of the lune for a roadway with a turn of radius 100 feet, if the two roadways make an angle of 60° with each other.

Solution.

$$X = R \operatorname{exsec} \frac{D}{2}$$

$$\operatorname{exsec} = \sec - 1 = \frac{1}{\cos} - 1$$

$$\therefore \quad \operatorname{exsec} \frac{D}{2} = \frac{1}{\cos \frac{D}{2}} - 1$$

$$\text{The angle} \quad \frac{D}{2} = 180° - \frac{60°}{2} - 90 = 60°$$

$$\therefore \quad X = 100\left(\frac{1}{.5} - 1\right) = 100\,(2 - 1) = 100'$$

$$R' = \frac{100 + 6}{1} \text{ (From Table)} = 106'$$

$$T' = 106 \times \tan 60° = 106 \times 1.732 = 185.6'$$

$$\text{Area of lune} = \frac{3.14 \times 120}{360} (\overline{100}^2 - \overline{106}^2) + (100 + 106)\,(T' - T)$$

$$T = R \tan \frac{D}{2} = 100 \times 1.732 = 173.2$$

$$\therefore \quad (T' - T) = 185.6 - 173.2 = 12.4$$

$$\therefore \text{ Area of lune} = \frac{3.14}{3}(-1236) + (206)\,(12.4) = 1260.7 \text{ sq. ft.}$$

Prob. 144*c*. Calculate X, R', T' and the area of the lune *bcdf* for a curve in a road with an angle of 75° and with a radius of 300 feet.

Prob. 144*d*. Repeat problem 144*b* for the following specifications:

Angle = 120 degrees
Radius = 200 feet.

TABLE XXII. — AREA OF CROSS-SECTION, CUBIC YARDS, QUANTITIES * OF MATERIALS REQUIRED PER LINEAR FOOT AND SQUARE YARDS OF SURFACE FOR CONCRETE ROADS FOR VARIOUS WIDTHS AND THICKNESSES SHOWN

Width, feet.	Thickness.			Area of cross-section, square feet.	Cubic yards concrete per linear foot of pavement.	Square yards per mile.	Cement, Barrels.		Sand, Cubic Yards.		Rock or pebbles, Cubic Yards.	
	Sides, inches.	Center, inches.	Average, inches.				1 : 2 : 3	1 : 1½ : 3	1 : 2 : 3	1 : 1½ : 3	1 : 2 : 3	1 : 1½ : 3
9	6	8	7.333	5.500	0.204	5,280	0.355	0.389	0.106	0.086	0.157	0.173
10	6	8	7.333	6.111	0.227	5,867	0.394	0.433	0.118	0.095	0.175	0.123
18	6	8	7.333	11.000	0.407	10,560	0.708	0.777	0.212	0.171	0.313	0.346
18	7	9	8.333	12.500	0.463	10,560	0.806	0.884	0.241	0.194	0.357	0.324
18	8	10	9.333	14.000	0.519	10,560	0.903	0.991	0.270	0.218	0.400	0.441
20	6	8	7.333	12.222	0.453	11,733	0.788	0.866	0.235	0.190	0.349	0.385
20	7	9	8.333	13.777	0.510	11,733	0.887	0.974	0.265	0.214	0.393	0.434
20	8	10	9.333	15.555	0.576	11,733	1.002	1.100	0.300	0.242	0.444	0.490
24	6	8	7.333	14.667	0.543	14,080	0.945	1.037	0.282	0.228	0.418	0.462
24	7	9	8.333	16.667	0.617	14,080	1.074	1.178	0.321	0.259	0.475	0.524
24	8	10	9.333	18.667	0.691	14,080	1.202	1.320	0.359	0.290	0.532	0.587
26	6	8½	7.667	16.611	0.615	15,253	1.070	1.175	0.320	0.258	0.474	0.523
26	7	9½	8.667	18.777	0.695	15,253	1.208	1.327	0.361	0.292	0.535	0.591
26	8	10½	9.667	20.944	0.776	15,253	1.350	1.482	0.404	0.326	0.598	0.660
27	6	9	8.000	18.000	0.667	15,840	1.161	1.274	0.347	0.280	0.514	0.567
27	8	11	10.000	22.500	0.833	15,840	1.449	1.591	0.433	0.350	0.641	0.708
30	6	9	8.000	20.000	0.741	17,600	1.289	1.415	0.385	0.311	0.571	0.630
30	8	11	10.000	25.000	0.926	17,600	1.611	1.769	0.482	0.389	0.713	0.787
36	6	9½	8.333	25.000	0.926	21,120	1.611	1.769	0.482	0.389	0.713	0.787
36	8	11½	10.333	31.000	1.148	21,120	1.998	2.193	0.597	0.482	0.884	0.976
40	6	10	8.667	28.888	1.070	23,467	1.862	2.044	0.556	0.449	0.824	0.910
40	8	12	10.667	35.555	1.317	23,467	2.292	2.515	0.685	0.553	1.014	1.119

Cement for 1 cu. yd. concrete { 1-1½-3 Mix. : 1.91 bbls.
1-2 -3 Mix. : 1.74 bbls.

Sand for 1 cu. yd. concrete { 1-1½-3 Mix. : 0.42 cu. yds.
1-2 -3 Mix. : 0.52 cu. yds.

Stone for 1 cu. yd. concrete { 1-1½-3 Mix. : 0.85 cu. yds.
1-2 -3 Mix. : 0.77 cu. yds.

* Based on 1 bbl. cement equals 4 cu. ft.: voids in stone, 45 per cent. Factors used from Taylor and Thompson's "Concrete, Plain and Reinforced."

CHAPTER XI

BUILDING FINISH

145. Plastering in General. Plaster work occurs in nearly all buildings and is so much used that it is wise to consider something of the general characteristics of the materials used and the method of applying it to the various types of structures. Plaster work is applied to **wood lath, metal lath, brickwork, tile walls** and to **concrete surfaces.**

Wood laths were the common base for nearly all plaster work until very recently, and are used to-day in some cases. The common woods for lathing are **pine** and **spruce.** The ordinary lath is $\frac{1}{4} \times 1\frac{1}{2} \times$ **48 inches.** This **provides a multiple of 12 and 16 inches,** the common spacing of joists and studs. In **ceiling work** the lath should be fastened by **5 nailings,** which necessitates a spacing of 12 inches for the joists or stripping. On **vertical surfaces** the studs may be spaced 16 inches on center, giving the lath **4 nailings.**

Metal lath is gradually supplanting wood lath for plaster work. In order to overcome the main objection to metal lath, that of rusting, the **lath should be galvanized, painted,** or **japanned.** This precaution is especially of importance where it is to be covered with a scratch coat of some chemical plaster. The other objection to metal lath is that it is hard to stretch tightly, but this is overcome by the **use of a ribbed lath** of some kind or another. Additional precautions can be taken to overcome this objectionable feature by **gauging** the **scratch coat** with **plaster of Paris.** This gives the plaster a rapid set and preserves the key.

146. Plaster Materials. Up to about 1885, all plaster work was of lime, sand, and hair. This mixture is a fairly good one if properly prepared. Some limes which are good for mortar are not good for plaster work as the stones from which they are burned contain substances which do not **slake well** and produce a gritty putty. Some of these particles slake later and cause the plaster to **pop.** This is due to the increase in volume incidental to slaking. Being confined in the surface they oftentimes produce large breaks in the plaster coat. It is therefore important that the builder make sure of the kind of lime he is getting, especially if he intends to slake it on the job. Even "**good name**" limes do not slake readily at times and it is good practice to slake them from **10 days to 2 weeks in advance** for the best classes of work.

Commercial **quicklime** or calcined (burned) limestone is produced by burning limestone at such a temperature that all the carbon dioxide is removed. The chemical formula of limestone is $CaCO_3$ (calcium carbonate) and when the carbon dioxide is driven off we have the chemical compound CaO. It is this product that is slaked and added to sand to form lime mortars. The slaking operation involves the addition of water (H_2O) to the CaO with the resultant formation of **Calcium Hydroxide** [$Ca(HO)_2$]. This compound is known as **slaked lime.**

When lump lime is used on the job, it often is slaked by laborers who are either careless or who do not appreciate the limitations of the process of slaking. If the amount of **water** which is added is **insufficient,** the **lime** is apt to **burn** in slaking. If the slaking operation is not allowed to go on for a sufficient length of time, small unslaked lumps of lime remain which later on slake in the wall and thus cause poor construction.

In order to insure a uniform, reliable product, various companies have been organized to produce a **hydrated lime** in much the same way as the Portland cement companies operate. These firms **watch their product carefully,** and one can always be assured of a good, well-slaked lime. It is slaked from carefully selected lime by mechanical means and chemists check up the content at stated intervals. In this way the contractor is relieved of the preparation of his slaked lime on the job and can use a product which is more easily handled and one which is sure to produce uniform results.

The purpose of the **sand** in plaster is **to prevent excessive shrinkage,** portions of it combining chemically with the lime to form silicate of calcium which is durable and of average waterproof qualities. The sand must be free from dust and dirt and should be washed to remove any salt which is apt to be in it. When the sand is to be used for the **white coat (finish coat)**, it should be screened to remove any large grains.

In order to make the parts of the mortar tie in, and to provide a mechanical bond in addition to the natural bond, **hair** or **fibre** is used. The hair is usually cow's hair put up in bushel paper bags. In the East large quantities of fibre are used. This is ordinarily Manilla fibre cut into 2-inch lengths. It is better to use than cattle's hair as it is usually cleaner and is attacked less by the lime.

147. Mixing Mortar for Plastering. The lime is slaked in a water-tight box and is customarily run through a sieve into another box, where it is allowed to stand for at least seven days. The hair is then soaked in water and pulled apart in order to make it spread more easily, and is beaten into the **putty** with a hoe. The proper amount of sand is then added and the whole is massed up into a pile and allowed to stand for not less than seven days. It is wet up in the amounts which will be used immediately. It is bad practice to mix the mortar in freezing weather and equally as bad for the building to mix it indoors, unless proper ventilation is provided for the escape of the steam incident to slaking.

Machines have been used extensively for the mixing of plaster mortar and they have their distinct advantages. The lime is thoroughly slaked by this process, and the mixing is rapidly and thoroughly done. This does away with the piles of mortar which are so often seen around buildings where plastering is in progress.

148. Proportions of Materials. The two types of plaster work usually come under what are known as **two-coat** or **three-coat** work. The first coat in either case is the **scratch coat,** and the second coat is called the **brown coat.** In two-coat work the brown coat is brought to the desired plane and finish in one operation, while in the three-coat work it is used to bring all the surfaces true and square, the finish coat being used for the purpose of finish only.

In good work the **scratch coat** should be a mixture of **1–2.** This is especially true where metal lath is used, as this insures a dense protective coating for the lath. The **brown coat** may be a **1–3** mixture. The finish coat or **white** (skim) **coat** is usually a mixture of **equal parts of lime putty and plaster of Paris** to which white sand or marble dust is added in the proportion of about **1–6.** These materials give the coat a hard polished appearance and are advised.

149. Hard Wall Plasters. The variations that have crept into the plaster work on buildings, due to the improper proportioning and mixing of materials, have tempted manufacturers to produce trade plasters that have a uniform character and can be counted upon to give like results at all times. These trade plasters are generally divided into two kinds, namely: **natural cement plasters** and chemical or **patented plasters.**

The natural cement plasters, so called, are merely **gypsum products,** and are sold by the trade names of **Acme, Agatite,** and **Royal.** These are the best known of this variety. The best known patented plasters are called **Adamant, Granite Wall, King's Windsor, Paragon, Rock Wall, Union Wall,** and **Victor Wall** plaster. They are all composed of a mixture of plaster of Paris, hydrated lime, asbestos, and a **retarder** in the form of glue stock or saccharine matter. The advantages of these products as above intimated lie in the fact that they are prepared from selected materials which are carefully weighed in proportioning. The manufacturers recommend that the mix for **lath** be **1–2,** and for **brick, tile,**

and terra-cotta, 1–3. The important thing to bear in mind in applying these plasters is that they **set** rather than harden, and not more should be mixed than can be applied in one and one-half hours.

The main advantages of these products are their **uniformity, greater hardness** and **tenacity, freedom from pitting, reduction of moisture and weight in the building, saving of time in the making** and **drying of the plaster, minimum danger from frost and greater resistance to fire and water.**

150. Quick Hardening Cements. A cement called **Sorel cement** or magnesia cement composed of light calcined magnesia (magnesium oxide) with magnesium chloride solution, hardens very quickly, attaining in twenty-four hours a strength of approximately that of a similar concrete of Portland Cement seven days old. This Sorel cement is used for inside finish, floors and stucco. It is sold under various trade names such as **Kellastone.** It will not stand the continued action of water, nor does it give fire resistance. The Sorel cement mortar can be applied in freezing weather.

Calcium chloride added to Portland cement up to 4 per cent accelerates the setting and increases the strength.

151. Application of Plaster. When plaster is applied to wood lath, the minimum **key** allowed should be **¼ inch with a ¾-inch ground,** but it is much better to use a **⅜-inch key and a ⅞-inch ground.** (Fig. 187.) All plasters and stuccos are applied with a steel float. The immediate supply of mortar is from a **hawk** (Fig. 188), and is removed from this tool by means of the steel float. It is applied with an upward pressure stroke so that the material will "**key**" through the lath. Too much pressure with a wet mortar causes the formation of too heavy a key and it drops off, making an unsatisfactory job. Where metal lath is used, the scratch coat should be **gauged,** as before mentioned, in order to produce a quick setting mixture which preserves the key that is formed.

When the plaster is to be applied to masonry walls, these should be **clean** and **rough,** in order to furnish as much natural key as possible. This is accomplished by scoring in tile, raked rough joints in brickwork, and roughened surfaces of concrete work. Plaster is easily applied to a concrete wall the surface of which has been brushed off when green. It is often customary to omit the hair or fibre in this work, but it is far better to take the extra precaution of including it

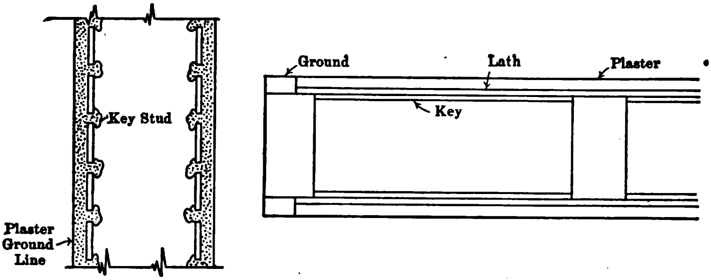


FIG. 187. PLAN AND SECTION OF WOOD STUDDED AND LATHED PARTITION SHOWING KEYS AND GROUNDS.

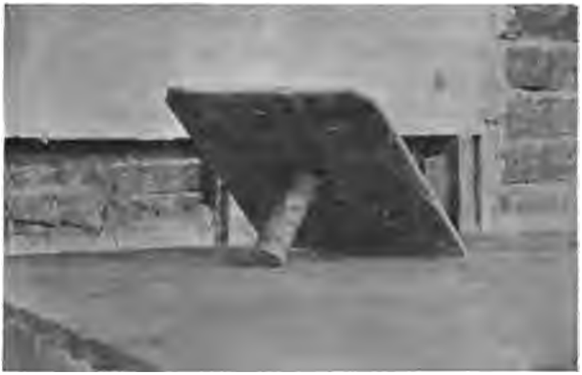


FIG. 188. THE WOOD HAWK.
This tool is used as a batch supply for the plasterer.

in the scratch coat, so as to get as much mechanical bond in addition to the natural bond as possible.

(*Perform Job No. 113, Vol. II.*)

152. Stucco. Inasmuch as stucco is becoming an integral part of modern concrete buildings in the form of plastered tile panels, and the like, it is worth our while to have the best and latest information on this subject. At the Convention of the **American Concrete Institute** recently held, the following **Report on Recommended Practice for Portland Cement Stucco was adopted.** It is here reproduced by permission of the Institute.*

RECOMMENDED PRACTICE FOR PORTLAND CEMENT STUCCO TO SUPERSEDE THE PRESENT STANDARD SPECIFICATION

153. Design of the Stucco Structure.

One of the fundamental considerations in successful stucco work is a suitable design of the structure **for stucco.** The architect does not always realize that an exterior plaster of any kind merits whatever protection can legitimately be given it, that for the sake of appearance it needs more protection against leakage and drip than brick, stone, or even wood exteriors. Thus it must be recognized that stuccoed copings, cornices, and horizontal or nearly horizontal surfaces are more exposed to deterioration than vertical surfaces, that attention to details of chimneys, downspouts, gutters, window sills, and overhead flashing will avoid much unnecessary staining and unsightly cracking. The committee therefore suggests the advisability of putting the paragraphs relating to "Structure" at the beginning of the specification, with one or more of these paragraphs relating to "Design" in so far as this has to do with protection for the stucco. These considerations suggest the following introductory paragraphs:

1. **Design.** Whenever the design of the structure permits, an overhanging roof or similar projection is recommended to afford protection to the stucco. Stuccoed copings, cornices and other horizontal surfaces should be avoided whenever possible. All exposed stuccoed surfaces should shed water quickly, and whenever departure from the vertical is necessary, as at water tables, belt courses, and the like, the greatest possible slope

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* Proc. A.C.I., Vol. XVI, 1920.

should be detailed. Stucco should not be run to the ground whenever other treatment is possible. Should the design of the structure require this treatment, the backing should be of tile, brick, stone, or concrete, providing good mechanical bond for the stucco, and should be thoroughly cleaned before plastering. Unless special care is taken to thoroughly clean the base and each plaster coat from dirt and splash before the succeeding coat is applied, failure of the stucco may be expected.

2. **Flashing.** Suitable flashing should be provided over all door and window openings wherever projecting wood trim occurs. Wall copings, cornices, rails, chimney caps, etc., should be built of concrete, stone, terra-cotta, or metal with ample overhanging drip groove or lip, and water-tight joints. If copings are set in blocks with mortar joints, continuous flashing should extend across the wall below the coping and project beyond and form an inconspicuous lip over the upper edge of the stucco. Continuous flashing with similar projecting lip should be provided under brick sills. This flashing should be so installed as to insure absolute protection against interior leakage. Cornices set with mortar joints should be provided with flashing over the top. Sills should project well from the face of the stucco and be provided with drip grooves or flashing as described above for brick sills. Sills should also be provided with stools or jamb seats to insure wash of water over the face and not over the ends. Special attention should be given to the design of gutters and downspouts at returns of porch roofs where overflow will result in discoloration and cracking. A 2-inch strip should be provided at the intersection of walls and sloping roofs and flashing extended up and over it, the stucco being brought down only to the top of the strip.

3. **Preparation of Original Surface.** All roof gutters should be fixed, and downspout hangers and all other fixed supports should be put in place before the plastering is done, in order to avoid breaks in the stucco.

Metal lath and wood lath should be stopped not less than 12 inches above grade to be free from ground moisture.

All trim should be placed in such manner that it will show its proper projection in relation to the finished stucco surface, particularly in overcoating.

154. Masonry Walls.

4. **Brick.** Surface brick should be rough, hard burned, commonly known as arch brick, or concrete which is not weak or

friable. Brick should be set in cement mortar with joints not less than ⅜ inch thick, and the mortar should be raked out for at least ½ inch from the face. The surface of the brick should be brushed free from all dust, dirt, and loose particles, and should be wetted to such a degree that water will not be rapidly absorbed from the plaster, but not to such a degree that water will remain standing on the surface when the plaster is applied.

Old brick walls which are to be overcoated should have all loose, friable, or soft mortar removed from the joints, and all dirt and foreign matter should be removed by hacking, wire brushing, or other effective means. Surfaces that have been painted or waterproofed should be lathed with metal lath before overcoating.

5. **Concrete.** Monolithic concrete walls should preferably be rough and of coarse texture, rather than smooth and dense, for the application of stucco. Walls of this type should be cleaned and roughened, if necessary, by hacking, wire brushing, or other effective means. The surface of the concrete should be brushed free from all dust, dirt, and loose particles, and should be wetted to such a degree that water will not be rapidly absorbed from the plaster, but not to such a degree that water will remain standing on the surface when the plaster is applied.

6. **Concrete Block.** Concrete block for stucco walls should be rough and of coarse texture, but not weak or friable. Block should be set with cement mortar joints, which should be raked out or cut back even with surface. Before applying the stucco the surface should be brushed free from all dust, dirt, and loose particles, and should be wetted to such a degree that water will not be rapidly absorbed from the plaster, but not to such a degree that water will remain standing on the surface when the plaster is applied.

7. **Tile.** Tile for exterior walls, columns, etc., should be hard burned clay with dovetail ragged scoring or concrete which is not weak or friable. Tile should be set in cement mortar composed of one part cement, not more than one-fifth part hydrated lime and three parts sand, by volume. The blocks should vary not more than ½ inch in total thickness and should be set with exterior faces in line. Joints should not be raked, but mortar should be cut back to surface. Neither wire mesh nor waterproofing of any type should be applied to tile walls before plastering. The surface of the tile should be brushed free from all dirt, dust, and loose particles, and should be wetted to such a degree that water will not be rapidly absorbed from the

plaster, but not to such a degree that water will remain standing on the surface when the plaster is applied.

In the foregoing paragraphs attention is called to the degree of wetting of the surface, which is important if best results are to be obtained. Too dry a surface will absorb the water from the plaster coat before the latter has had time to obtain its set, whereas a surface which is completely saturated is likely to be covered with a thin film of water, which will prevent proper bond of the plaster coat.

155. Frame Walls.

8. **Framing.** Studs spaced not to exceed 16-inch centers should be run from foundation to rafters without any intervening horizontal members. The studs should be tied together just below the floor joists with 1 × 6-inch boards which should be let into the studs on their inner side, so as to be flush and securely nailed to them. These boards will also act as sills for the floor joists, which, in addition, should be securely spiked to the side of the studs.

9. **Bracing.** The corners of each wall should be braced diagonally with 1 × 6-inch boards let into the studs on their inner side, and securely nailed to them.

(*a*) * At least once midway in each story height the studs should be braced horizontally with 2 × 3-inch bridging set 1 inch back of the face of the studs.

(*b*) No bridging is necessary.

10. **Sheathing.** (*a*) The lath should be fastened direct to the studding and back plastered, and no sheathing is used.

(*b*) Sheathing boards should not be less than 6 inches nor more than 8 inches wide, dressed on one or both sides to a uniform thickness of ⅞ inch. They should be laid horizontally across the wall studs and fastened with not less than two 8*d.* nails at each stud.

11. **Inside Waterproofing.** (*a*) No waterproofing is necessary.

(*b*) Over the sheathing boards should be laid in horizontal layers, beginning at the bottom, a substantial paper, well impregnated with tar or asphalt. The bottom strip should lap over the baseboard at the bottom of the wall, and each strip should lap the one below at least 2 inches. The paper should lap the flashings at all openings.

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* Paragraphs marked (*a*) apply only to back-plastered construction in which sheathing is omitted. Paragraphs marked (*b*) apply only to sheathed walls. The paragraphs relating to bridging assume that studs are 2 × 4 inches. Larger sizes would require correspondingly larger bridging.

12. **Furring.** Metal Lath. When furring forms an integral part of the metal lath to be used, then separate furring as described in this paragraph is omitted.

(*a*) Galvanized or painted ⅜-inch crimped furring, not lighter than 22-gage or other shape giving equal results, should be fastened direct to the studding, using 1¼-inch × 14-gage staples spaced 12 inches apart.

(*b*) Galvanized or painted ⅜-inch crimped furring, not lighter than 22-gage or other shape giving equal results, should be fastened over the sheathing paper and directly along the line of the studs, using 1¼-inch × 14-gage staples spaced 12 inches apart. The same depth of furring should be adhered to around curved surfaces, and furring should be placed not less than 1½ inches nor more than 4 inches on each side of and above and below all openings.

Wood Lath. Furring 1 × 2-inch should be laid vertically 12 inches on centers over the sheathing paper and nailed every 8 inches with 6*d*. nails.

13. **Lath.** Metal lath should be galvanized or painted expanded lath weighing not less than 3.4 pounds per square yard.

Wire lath should be galvanized or painted woven wire lath, not lighter than 19-gage, 2½ meshes to the inch, with stiffeners at 8-inch centers.

Wood lath should be standard quality, narrow plastering lath 4 feet long and not less than ⅜ inch thick.

14. **Application of Lath.** Metal Lath. Lath should be placed horizontally driving galvanized staples 1¼-inch × 14-gage not more than 8 inches apart over the furring or stiffeners. Vertical laps should occur at supports and should be fastened with staples not more than 4 inches apart. Horizontal joints should be locked or butted and tightly laced with 18-gage galvanized wire.

Wood Lath. Lath should be placed horizontally on the furring with ½-inch openings between them. Joints should be broken every twelfth lath. Each lath should be nailed at each furring with 4*d*. nails.

15. **Corners.** Metal Lath. The sheets of metal lath should be folded around the corners a distance of at least 3 inches and stapled down, as applied. The use of corner bead is not recommended.

·Wood Lath. At all corners a 6-inch strip of galvanized or painted metal lath should be firmly stapled over the wood lath with 1¼-inch × 14-gage galvanized staples.

16. **Spraying.** Before applying the first coat of plaster, wood lath should be thoroughly wetted, but water should not remain standing on the surface of the lath when the plaster is applied.

17. **Insulation.** The air space in back-plastered walls may be divided by applying heavy building paper, quilting, felt, or other suitable insulating material between the studs, and fastening it to the studs and bridging by nailing wood strips over folded ends of the material. This insulation should be so fastened as to leave a greater air space next to the interior plaster. Care should be taken to keep the insulating material clear of the outside plaster, and to make tight joints against the wood framing at the top and bottom of the space and against the bridging.

156. Materials.

18. **Cement.** The cement should meet the requirements of the standard specifications for Portland cement of the American Society for Testing Materials, and adopted by this Institute. (Standard No. 1.)

19. **Fine Aggregate.** Fine aggregate should consist of sand, or screenings from crushed stone or crushed gravel, graded from fine to coarse, passing when dry a No. 8 screen. Fine aggregate should preferably be of silicious materials, clean, coarse, and free from loam, vegetable or other deleterious matter. In this connection reference may be made to the recently developed colorimetric test for detecting the presence of organic matter in sands.

20. **Hydrated Lime.** Hydrated lime should meet the requirements of the standard specifications for hydrated lime of the American Society for Testing Materials.

21. **Hair or Fibre.** There should be used only first quality long hair, free from foreign matter, or a long fibre well combed out.

22. **Coloring Matter.** Only mineral colors should be used which are not affected by lime, Portland cement, or other ingredients of the mortar, or the weather.

23. **Water.** Water should be clean, free from oil, acid, strong alkali, or vegetable matter.

157. Preparation of Mortar.

24. **Mixing.** The ingredients of the mortar should be mixed until thoroughly distributed and the mass is uniform in color and homogeneous. The quantity of water necessary for the desired consistency should be determined by trial, and thereafter measured in proper proportion.

Machine Mixing. The mortar should preferably be mixed in a suitable mortar mixing machine of the rotating drum type. The period of machine mixing should be not less than five minutes after all the ingredients are introduced into the mixer.

Hand Mixing. The mixing should be done in a water-tight mortar box, and the ingredients should be mixed dry until the mass is uniform in color and homogeneous. The proper amount of water should then be added and the mixing continued until the consistency is uniform.

25. **Measuring Proportions.** Methods of measurement of the proportions of the various ingredients, including the water, should be used which will secure separate uniform measurements at all times. All proportions stated should be by volume. A bag of cement (94 pounds net) may be assumed to contain 1 cubic foot. Forty pounds may be assumed as the weight of 1 cubic foot of hydrated lime. Hydrated lime should be measured dry, and should not be measured nor added to the mortar in the form of putty.

26. **Retempering.** Mortar which has begun to stiffen or take on its initial set should not be used.

27. **Consistency.** Only sufficient water should be used to produce a good workable consistency. The less water, the better the quality of the mortar, within working limits.

158. Mortar Coats.

28. **Mortar.** All coats should contain not less than 3 cubic feet of fine aggregate to 1 sack of Portland cement. If hydrated lime is used, it should not be in excess of one-fifth the volume of cement. Hair or fiber should be used in the scratch coat only on wood lath, or metal or wire lath which is applied over sheathing and is separated therefrom by furring deeper than ⅜ inch.

29. **Application.** The plastering should be carried on continually in one general direction without allowing the plaster to dry at the edge. If it is impossible to work the full width of the wall at one time, the joining should be at some natural division of the surface, such as a window or door.

The first coat should thoroughly cover the base on which it is applied and be well troweled to insure the best obtainable bond. Before the coat has set it should be heavily cross-scratched with a saw-toothed metal paddle or other suitable device to provide a strong mechanical key.

The second coat should be applied whenever possible on the day following the application of the scratch coat. The first coat should be dampened if necessary, but not saturated, before the second coat is applied. The second coat should be brought to a true and even surface by screeding at intervals not exceeding 5 feet, and by constant use of straightening rod. When the second coat has stiffened sufficiently, it should be dry floated with a wood float and lightly and evenly cross-scratched to form a good mechanical bond for the finish coat. The day following the application of the second coat, and for not less than three days thereafter, the coat should be sprayed or wetted at frequent intervals and kept from drying out.

In back-plastered construction the backing coat should preferably be applied directly following the completion of the brown coat. The keys of the scratch coat should first be thoroughly dampened, and the backing coat then well troweled on to insure filling the spaces between the keys and thoroughly covering the back of the lath. The backing coat should provide a total thickness of plaster back of the lath of ⅝ inch or ¾ inch, and should finish about ¼ inch back of the face of the studs.

The finish coat should be applied not less than a week after the application of the second coat. Methods of application will hereinafter be described under "finish."

30. **Two-coat Work.** Whenever two-coat work is required the first coat should preferably be "doubled," that is, as soon as the first coat is stiff enough, it should be followed by a second application of mortar, and this should then be treated as described for the second coat under paragraph 29. The finish coat should be applied not less than a week after the application of the first coat.

31. **Drying Out.** The finish coat should not be permitted to dry out rapidly, and adequate precaution should be taken, either by sprinkling frequently after the mortar is set hard enough to permit it, or by hanging wet burlap or similar material over the surface.

32. **Freezing.** Stucco should not be applied when the temperature is below 32° F., nor under any conditions such that ice or frost may form on the surface of the wall.

159. Finish.

33. **Stippled.** The finishing coat should be troweled smooth with a metal trowel with as little rubbing as possible, and then should be lightly patted with a brush of broom straw to give an even, stippled surface.

34. **Sand Floated.** The finishing coat, after being brought to a smooth, even surface, should be rubbed with a circular motion of a wood float with the addition of a little sand to slightly roughen the surface. This floating should be done when the mortar has partly hardened.

35. **Sand Sprayed.** After the finishing coat has been brought to an even surface, it should be sprayed by means of a wide, long fiber brush — a whisk broom does very well — dipped into a creamy mixture of equal parts of cement and sand, mixed fresh at least every 30 minutes, and kept well stirred. This coating should be thrown forcibly against the surface to be finished. This treatment should be applied while the finishing coat is still moist and before it has attained its early hardening, that is, within 3 to 5 hours. To obtain lighter shades add hydrated lime not to exceed 10 per cent of the weight of the cement. (1 to 3 minimum.)

36. **Rough-Cast or Spatter Dash.** After the finishing coat has been brought to a smooth, even surface with a wooden float and before finally hardened, it should be uniformly coated with a mixture of one sack cement to 3 cubic feet of fine aggregate thrown forcibly against it to produce a rough surface of uniform texture when viewed from a distance of 20 feet. Special care should be taken to prevent the rapid drying out of this finish by thorough wetting down at intervals after stucco has hardened sufficiently to prevent injury.

37. **Pebble Dash.** After the finishing coat has been brought to a smooth, even surface, and before it has begun to harden, clean round pebbles, or other material as selected, not smaller than ¼ inch or larger than ¾ inch and previously wetted, should be thrown forcibly against the wall so as to embed themselves in the fresh mortar. They should be distributed uniformly over the mortar with a clean wood trowel, but no rubbing of the surface should be done after the pebbles are embedded.

38. **Exposed Aggregates.** The finishing coat should be composed of an approved, selected coarse sand, crushed marble, or granite or other special material, in the proportion given for finishing coats, and within 24 hours after being applied and troweled to an even surface, should be scrubbed with a stiff

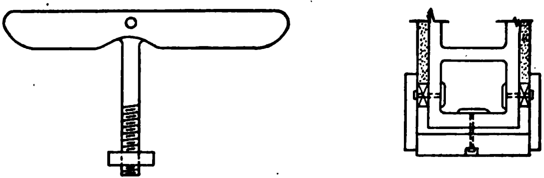
brush and water. In case the stucco is too hard, a solution of one part hydrochloric acid in four parts of water by volume can be used in place of water. After the aggregate particles have been uniformly exposed by scrubbing, particular care should be taken to remove all traces of the acid by thorough spraying with water from a hose.

39. **Mortar Colors.** When it is required that any of the above finishes should be made with colored mortar not more than 10 per cent of the weight of Portland cement should be added to the mortar in the form of finely ground mineral coloring matter.

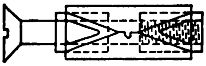
A predetermined weight of color should be added dry to each batch of dry fine aggregate before the cement is added. The color and fine aggregate should be mixed together and then the cement mixed in. The whole should be then thoroughly mixed dry by shoveling from one pile to another through a $\frac{1}{4}$-inch mesh wire screen until the entire batch is of uniform color. Water should then be added to bring the mortar to a proper plastering consistency.

This is the most complete information on the subject of **stucco** at hand and should be thoroughly studied.

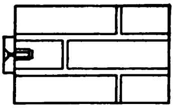
160. Erection of Trim. The securing of **trim** to frame and masonry walls is a troublesome, yet important, item in the satisfactory completion of such a building as this. In Chapter IX, in connection with the setting of frames, the subject of nailing strips and blocks was discussed. The location of a sufficient number of such strips should be studied in advance, thus avoiding much trouble later. Lengthy, wordy descriptions of this work are unsatisfactory and to dispense with these the student should examine the possibilities of the use of strips, toggles, sleeves, and joint nailing bases as shown on Plate XVIII. These illustrate the methods used for providing nailings for the trim. The student should study these in connection with the actual erection of the parts of the building finish, and thus obtain a knowledge of the limitations of the materials and methods, devising new schemes, if possible. **This field is undeveloped** at present and much can be done to make this sort of work more satisfactory.



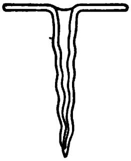
TOGGLE BOLT USED FOR TILE CLIP



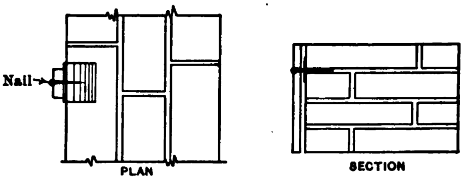
EXPANSION SLEEVE



BRICK OR CONCRETE FASTENING FOR NAILING STRIP



WALL PLUG



PLAN

SECTION

WALL PLUG IN BRICK WALL

Plate XVIII. Nailings for Masonry Walls.

161. Concrete Surface Finishes. Some of the possible finishes on concrete were illustrated in connection with the concrete block industry. Increasing attention is being paid to the appearance of concrete surfaces, particularly in city structures. Ordinary cement surfaces are dull in color, and are likely to be marred by marks, cracks, holes, patchy areas, and efflorescence. It is very difficult, too, to blend concrete surfaces in order to have new material match the old.

For ordinary work such as piers, abutments, and walls, a satisfactory surface is secured by smooth, tight and rigid forms, against which the concrete is spaded carefully. Special treatments are obtained by:

Scrubbing,
Rubbing,
Tooling,
Sand-Blasting,
Acid Treatment.

Scrubbing the concrete surface with a stiff brush and water before the surface has had a chance to harden will remove the inequalities. The dead appearance of the cement is also relieved by the exposure of the sand. When the concrete is too hard for fibre brushes, a wire brush can be used with excellent results. The time of removing the forms depends upon the cement, consistency of the concrete, weather and character of work.

When a rubbed surface is wanted, the concrete is allowed to become slightly harder than for the scrubbed surface, and the concrete is rubbed down with brushes, carborundum, emery, concrete, or soft natural stones along with a thin grout of sand and cement. The grout fills in surface irregularities, and the surplus can later be rubbed or washed off. When this work is done, all rough spots or pockets in the concrete should be painted or patched, and all wires or nails should be cut off flush with the surface.

Tooled surfaces are often specified in concrete work. This is done after the concrete has hardened for about two weeks. The bush-hammer, crandall, or axe are used for this work when it is done by hand. The **Berg Rotary Surfacer,** a pneumatic tool, will produce excellent results when it is desired to do the work by machine. Where the aggregate of the concrete is gravel, care must be used to prevent the forcing out of the pebbles.

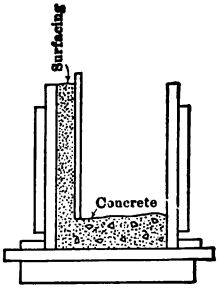


FIG. 189. CASTING SURFACED CONCRETE.

The steel or wooden pallet is set and the surfacing mortar is cast behind it. As the backing concrete is cast the pallet is withdrawn. The tamping of the concrete establishes a good bond between the two materials.

Very often the surface coat of cement is removed by means of the sand-blast. This is applied after the ridges (fins) left by the forms have been removed by tooling. **All edges and joints which** are to **form** a **part of the architectural treatment** of the surface **must be protected** by wood strips or the blast will dull them.

The treatment of surfaces with acid washes is becoming quite common. **Muriatic acid diluted 1–6** is washed on the surface to remove the surface cement, and the concrete is then scrubbed with stiff brushes.

In order to produce the exact color and texture desired the use of a **facing mortar of selected aggregate** is often used. A steel plate about 10 inches wide and 6 feet long is placed about 1½ inches from the form and the mortar is placed. The concrete for the backing is then poured and the plate raised before the concrete or mortar has set. (Fig. 189.)

162. Glass and Glazing. The two kinds of glass that are used in building work are either blown or cast. The ordinary kind of window glass is called **sheet glass.** It is made by blowing a cylinder of plastic glass which is subsequently cut open and after reheating is spread out upon an iron plate and annealed in ovens. This kind of glass does not run uniform in quality or thickness and is very often marked with air bubbles and tension planes. It is blown in two thicknesses; $\frac{1}{16}$ and $\frac{1}{8}$ **inch.** The thinner sheet is called **single thick,** while the other is called **double thick.** Because of the irregularities that exist in sheet glass, it is graded into **first, second,** and **third** quality glass. The first is called "**AA,**" the second "**A,**" and the third "**B**" quality. Anything inferior to this is sold as **Stock Sheets.** The maximum size in which single thick glass can be obtained is 28 × 34 inches, double thick running up to 40 × 60 inches.

Plate glass, which is used for all large panes and where a uniform quality is desired, is cast. The material is selected with very great care, melted in large pots and cast upon a perfectly flat cast-iron table. The **guns,** which determine the width and thickness of the plate, are fastened upon the table and accommodate a heavy metal roller. The molten metal is poured into the hollow rectangular dish, the roller passing along slowly pressing the **metal,** so-called, before it. It is then annealed and is known as **rough plate.** In this form it is used for **vault-lights, skylights,** and **floor-lights.** The polished plate glass is made from this rough plate by rubbing on a revolving circular table which has shodded polishing **shoes,** which revolve in the opposite direction to the table. The grinding is done first with sand which is gradually reduced to a finer quality, the finishing being done with water and iron oxide. This reduces the thickness to about $\frac{1}{4}$ or $\frac{1}{5}$ of an inch. The glass is then cut up into the largest sheets that can be made from the pieces, and can be bought in sizes from a piece **6** × **6 inches** to **144** × **240 inches,** or **138** × **260 inches.**

By a similar process the various kinds of **figured glass** are made. The plate upon which the glass is cast has the figures upon it. Some of the trade names which are applied to this kind of glass are **Moss, Maze, Colonial, Florentine, Cobweb,** and so forth. This glass can be had in sizes **24** to **44 inches** wide and from **8** to **10 feet** long. It is usually about $\frac{1}{8}$ inch thick, with or without **wire** mesh. The use to which this sort of glass is put combines the necessities of light and privacy, such as one would expect to have in office doors and partitions.

The glass usually specified for the metal sash of buildings of this kind would be **¼-inch plate, ⅛- or ¼-inch ribbed, ¼-inch rough** or **ribbed wire glass,** or **polished plate wire glass.** Any glass would be set into the frame with a **putty** and some form of **clip,** which takes the form of a **zinc point** where wood frames are used. The setting of glass in frames such as we have in this building is shown in Fig. 190.

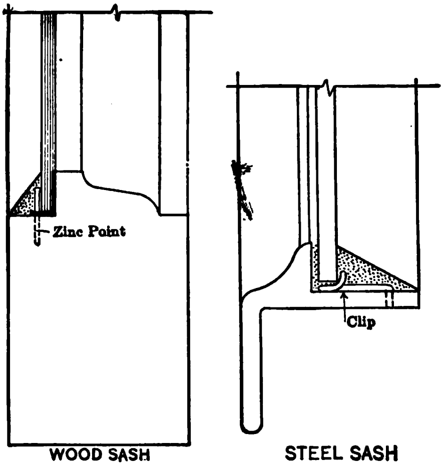


FIG. 190. SETTING GLASS IN WOOD AND STEEL SASH.

In the wood sash the zinc point is used to fasten the glass, while in the steel sash the wire clip is employed.

Prob. 162*a*. How many square feet of glass in a Z 45161 sash if the panes of the vent are ⅞ inch narrower and ⅞ inch shorter, due to the steel framing of the sash?

Prob. 162*b*. How many panes 14 × 20 and 13⅞ × 19⅞ are there in one of the 3-unit steel sash in this building?

Prob. 162*c*. Make a glass schedule for all the sash and doors in this building as suggested:

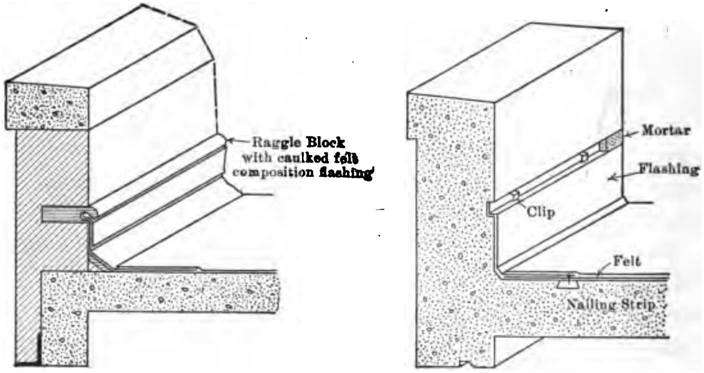
Size	Number of panes	Type	Square feet
Ins. 14 × 20		Ins. ⅛ factory ribbed	
13⅛ × 19⅛			
		¼ pol. plate	

163. Concrete Roof Surfaces. Roofs, "from time immemorial," have been the cause of extensive later repairs due to leaks. Contractors generally try to guard against leaks in concrete roofs, realizing the tendency concrete has to crack or check under the action of moisture and temperature. Many methods have been used to accomplish this end, among which **special reinforcement,** ~~called~~ temperature steel, **waterproofing, roof coverings, flashings,** and **special surfaces** are the most common.

The action of the various means of protection named above may be divided under two main headings, namely, **protection against cracking,** as in the case of reinforcement, and **protection against water absorption,** as is the case with the other materials. Waterproofing has been attempted in the shape of rich mixes of concrete with a well graded aggregate for maximum density, by applying rich granolithic coatings, and by painting the surfaces with waterproof paints. Integral waterproofing compounds have been used to a great extent and with some success, but in general it may be said that a **combination** of one of the above precautions with the use of reinforcement and some protective covering in the form of felt or prepared roofing is the most satisfactory.

The use of tar and gravel roofing is very common on concrete roof surfaces. The **Barrett Company's Specification** is considered standard for this work, and the student is referred to this company's catalogs for the wording of it. In general, the method followed is to coat the concrete with a layer of hot pitch mopped on uniformly. Over this two layers of felt are placed, each sheet lapping the other about 17 inches and carefully mopped with pitch. The entire roof surface is then mopped with pitch after which three more layers of felt are applied in a similar manner, each lapping the other about 22 inches. The entire surface is again coated with hot pitch, and, while it is still hot, the gravel or slag is bedded upon it.

164. Roof Drainage and Flashings. The pitching of the roof to **provide proper drainage** is something that should always be studied carefully in order that all the water will be taken care of at the points of discharge. To accomplish this the roof slab itself may be pitched in some general direction and the points of interference at curbs, chimneys, and



(*a*) (*b*)

FIG. 191. PARAPET FLASHINGS.

Note the method of fastening to the wall and to the slab, and the number of layers of material.

(*a*) Raggle block cap flashing for brick walls.

(*b*) Wedged metal cap flashing for concrete walls.

parapets provided with **saddles** as shown on the roof plan of this building. If it is desired to retain a level ceiling, the pitch is provided with saddles of cinder concrete coated with a concrete mortar surface. This method increases the weight of the dead load on the slab and thus the size of the members. It is advisable sometimes even with this disadvantage.

At all points where the walls or other parts of a building extend above the roof a **flashing** is provided. This is usually composed of two parts; the **cap flashing** and the **base flashing**. Various methods have been used for this part of the work and two of the most common are illustrated in Fig. 191. When the cap flashing is of metal or of some plastic material, wood nailing strips must be provided in the wall and the slab. The strip in the wall is at times replaced with a metal clip, a raggle block, or by cementing the cap directly upon the concrete surface, as is the case with the Johns-Manville flashing.

165. Disposal of Roof Water. The general method employed in disposing of rain water from roofs is by the means of **gutters** and **downspouts.** The gutters are hung from the low end of the roof slab and are **pitched toward the downspouts.** The detail of the connection of a gutter to the roof slab is

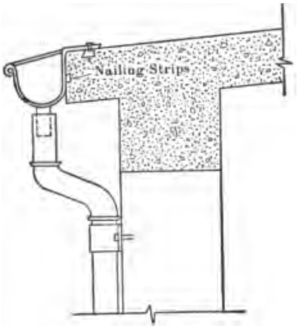


FIG. 192. GUTTER CONNECTION TO THE ROOF SLAB.

Nailing strips are provided in the top and end of the roof slab.

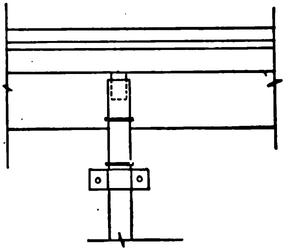


FIG. 193. ROOF DRAIN AND CONNECTION.

shown in Fig. 192. At times the architect wishes to keep his building uniform all around and he builds a parapet clear around the building. In this case he pitches his roof toward a roof drain which connects with a downspout, usually within the building. The details of such a construction are shown in Fig. 193.

166. Parapets. Parapets may be built either of brick or concrete. The general details of either construction are the same and as above discussed. The **main difference** is **in** the **materials used** and care should be taken that the brick used for such construction are **hard burned or vitrified brick.** The weathering qualities of the parapet are more often the determining factors in the life of the roof than anything else except the roof covering itself. When built of concrete, care should be taken to obtain as **dense a concrete** as possible and one that is protected by other means than by this material alone, such as coverings and flashings.

167. Hardware. It is not the intention to include a complete discussion of hardware in this text, but the student is reminded that ordinarily this is covered by the specifications, and a hardware salesman usually presents an **itemized proposal** for the entire job, which it is the builder's province to investigate. Many extensive catalogs have been prepared, and the ability to place one's hand upon the proper fittings for the proper places should be developed by the student by a careful study of such a list. The J. B. Hunter Company of Boston has prepared such an itemized proposal for this building, and it should be studied in connection with the plans and the companies' catalogs.

VISE SHOP, LAWLOR COMPANY, AUSTIN, CONN.

Ground Floor

Outside Entrance Door to Vestibule, RH., 2¼ inches

1½ pr. No. 750 Butts 5 × 5 inches, BZ 10
1 set No. 472¼ MK. lock × GR23414, BZ10
1 No. 73 Door closer, GB

1		GT1533 × GT1527, letter hole trim, BZ10
1		No. 805 Door stop, BZ10
1		Kick plate 10 inches wide × width of door

Transom over Main Entrance Door:

1	pr.	No. 725 Butts 3 × 3 inches, BZ10
1		No. 376¾ Transom catch, BZ10
2		No. 1293 Transom chains, 12-inch, BZ10

Vestibule to Main Office, RHRB., 1¾ inches

1½	pr.	BB239 Butts 4 × 4 inches
1	set	No. 656 MK. × D35 × GR86, BZ10
1		No. 73 Door closer, GB
1		No. 805 Stop, BZ10

Vestibule to Stenographer's Toilet, RH., 1¾ inches

1½	pr.	BB239 Butts, N finish
1	set	No. 790 × D35 × GR86, BZ10 × NZ10
1		No. 73 Door closer, NV10
1		No. 812 Stop, NZ10

Vault Door

Hardware furnished by others

Shop to Office, LHR. 1¾ inches

1½	pr.	BB239 Butts 4 × 4 inches, BZ10
1	set	No. 656 MK × D35 × GR86, BZ10
1		No. 73 Door closer, GB
1		No. 805 Stop, BZ10

Shop to Workmen's Toilet, RH. 1¾ inches

1½	pr.	BB239 Butts 4 × 4 inches, N finish
1	set	No. 790 × D35 × GR86, BZ10 × NZ10
1		No. 73 Door closer, NV10
1		No. 812 Door stop, NZ10

12 Double-Hung Windows

10	No. 834 Sash fasts, BZ10
18	A 1358 Sash lifts, BZ10
10	No. 1243 Sockets, BZ10
120	No. 734 Adjustable stop bead screws, BZ10
2	No. 842 Fasts, NZ10
2	No. 1358 Sash lifts, NZ10
2	No. 1243 Sash sockets, NZ10
20	No. 734 Adjustable stop bead screws, NZ10

Also

2	No. 1271 Pole Hooks, BZ10
2	No. 1269 Hangers, BZ10
2 doz.	No. 418 Clothes hooks, B

Rolling Door to Platform

1	No. 850 Padlock, MK.

All locks master keyed in one set and make provision for future additions under same master key

2 Master keys to be furnished.

J. B. Hunter Company, Boston, Mass.

Prob. 167*a*. What is meant by the trade letters BZ10? GB? N? NZ10? NV10? MK? (Consult Yale and Towne Hardware Catalog.)

Prob. 167*b*. Describe a No. 472½ MK lock × GR23414 set. A No. 656 MK × D35 × GR86 set.

Prob. 167*c*. Write a discussion on hardware explaining the trade indications of style, finish, material, etc.

168. Problems for Review

Prob. 168*a*. Make an estimate sheet of the metal flashings required for this building, as if they had been specified.

Prob. 168*b*. How many linear feet of raggle block would be necessary to flash this building?

Prob. 168*c*. Price the hardware schedule given under Art. 167.

CHAPTER XII

SPECIAL CONCRETE CONSTRUCTIONS

169. The Concrete Silo. One of the very necessary buildings attached to the modern farm, and one which embodies principles of construction in reality as comprehensive as many city operations, is the **concrete silo.**. Its importance in connection with modern farm practice is evidenced by the increase from 91 in 1882 to 500,000 in 1917 in the United States alone.

The silo must be airtight, windproof, waterproof, fireproof, permanent, and rat- and vermin-proof. In order that all these conditions may be met, it is advisable to use some one material which will insure all these means of protection.

The advantages of concrete in the construction of these structures are many-sided. Concrete produces a construction which is **waterproof** and **weather-resisting,** and which can be made with all the **conveniences** of the old wood-stave silo. It can be constructed **monolithic** as in Fig. 194, or as a **stave silo** as shown in Fig. 195.

170. Absorptive Properties of Concrete. The **importance of waterproofing is two-fold** in silo construction. The elements must not penetrate the wall nor should it be possible for the silage juices to leak out. The greater the permeability of the concrete, the more apt is the air to gain entrance. This causes bacterial action and resultant fermentation, extremely detrimental to the silage.

The most important results that experimentation has produced to date show that **permeability decreases with the age of the concrete, decreases with the continuation of the flow,** and **increases with the leanness of the mixture and the coarseness**

of the sand. These items again place renewed emphasis upon a fairly **rich mix** made of **well-proportioned** aggregates and **cast** in as **continuous** a fashion as possible.

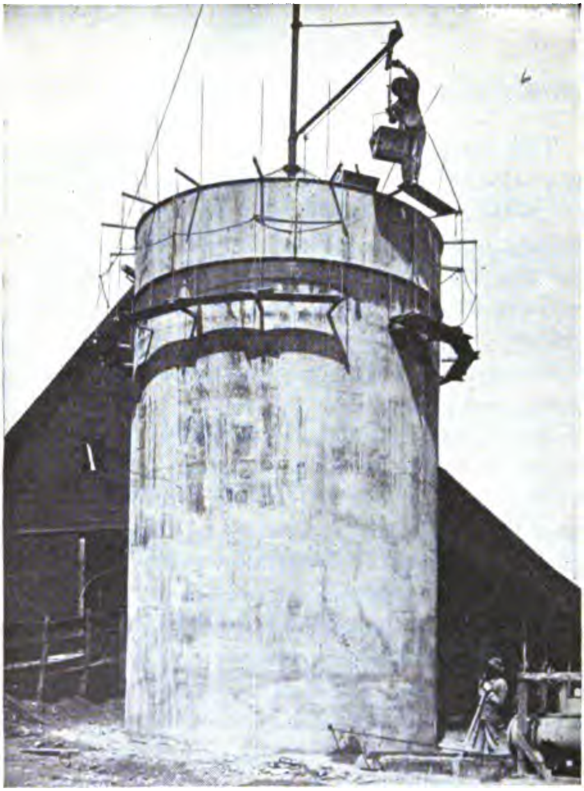


FIG. 194. THE MONOLITHIC SILO.

171. Construction of the Silo. The excavation for **concrete silos** is carried to a point below frost to prevent subsequent heaving. The foundation is then cast in a solid block so that the silo floor will not be more than 4 feet below grade.

The common types of **staves** are from 28 to 30 **inches long,** 10 to 12 inches wide, and from 2½ to 3 inches thick. They are provided with special end and side **lugs** for jointing, and are grouted into place in the best work, being banded with **steel hoops** as shown in Fig. 195. The first course of staves is set upon the foundation, and **full** and **part length staves** are **alternated.** This provides broken joints. The hoops are then tightened and all the slack is taken up. This is continued to the proper height. The interior of the silo is then painted with a thick creamy grout. The whole is then roofed either with wood or corrugated iron. By constructing the first five or six feet of a small silo in actual practice, the student will become familiar with this method of construction.

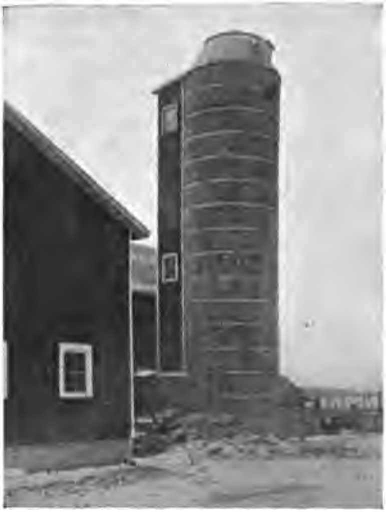


FIG. 195. THE STAVE SILO.

172. Capacities. For the convenience of the student who may be called upon to erect such a construction, the following table is given from the records of the Portland Cement Association.

TABLE XXIV

APPROXIMATE CAPACITY OF ROUND SILOS

(Diameter is shown at the top of the columns and depth at the left)

Height of silo	Inside diameter of silo in feet and the capacity in tons										
	10 feet	11 feet	12 feet	13 feet	14 feet	15 feet	16 feet	17 feet	18 feet	19 feet	20 feet
Feet	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons
28	42	51	61	71	83	.....	.....	.....	.....	.....	.....
30	47	56	67	79	91	105	.....	.....	.....	.....	.....
32	51	62	74	86	100	115	131	.....	.....	.....	.....
34	56	68	80	94	109	126	143	162	.....	.....	.....
36	61	73	87	102	118	136	155	176	196	.....	.....
38	66	79	94	110	128	148	167	191	212	237	.....
40	70	85	101	119	138	160	180	205	229	256	280
42	....	91	109	128	148	172	193	218	244	270	299
44	....	....	117	137	159	184	207	233	261	289	320
46	....	....	....	....	170	197	222	247	277	307	340
48	....	....	....	....	....	.....	236	261	293	325	361
50	....	....	....	....	....	.....	.....	.....	310	344	382

Prob. 172*a*. If a silo 15 feet in diameter and 30 feet high holds 105 tons, what is the capacity in pounds per cubic foot?

Prob. 172*b*. Check the values in Plate XXIV in the light of Problem 172*a* for a silo 40 feet high.

Prob. 172*c*. Using a scale of ⅛ inch to 2 feet of height as ordinates and ⅛ inch to 10 tons of capacity as abscissæ, plot the curves for silos ranging in diameter from 10 to 20 feet.

173. Small Tanks. Plate XIX shows the plans for a small water tank adapted from the plans of a low standpipe in Ontario, Canada. This is a small conception of what has been accomplished in concrete tanks and towers such as shown in Figs. 64 and 68, pp. 772 and 775 of Hool and Johnson's Concrete Engineers' Handbook. The principles which we are interested in here are the same for all, the structural considerations for these high tank towers being similar to that of the building we have discussed in Chapters I to XI.

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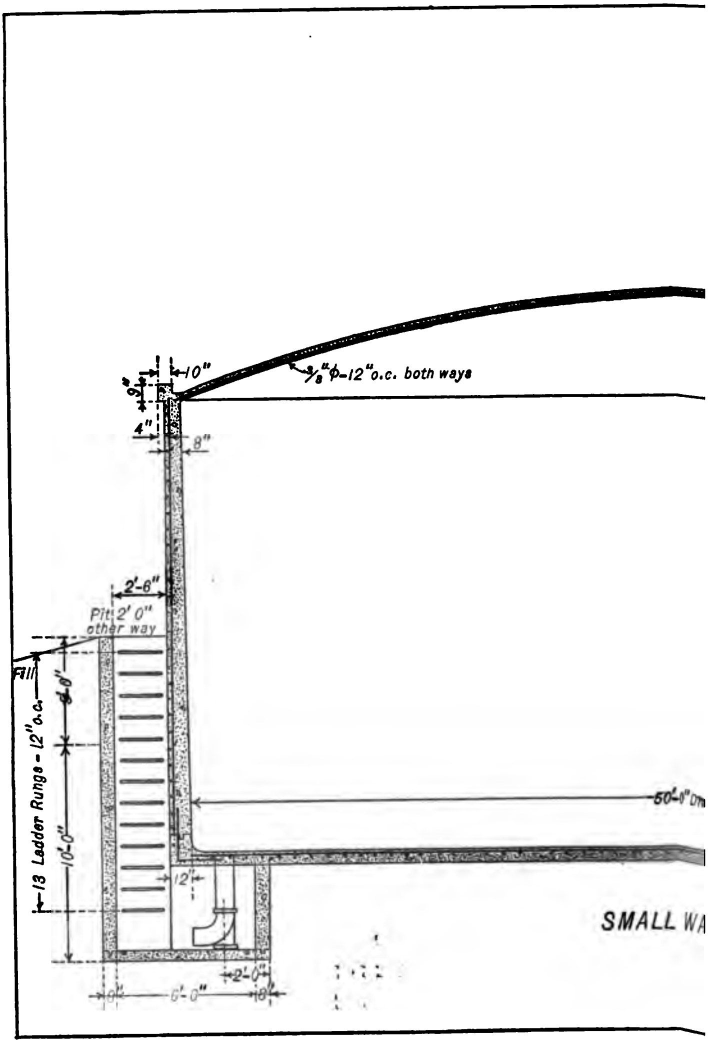
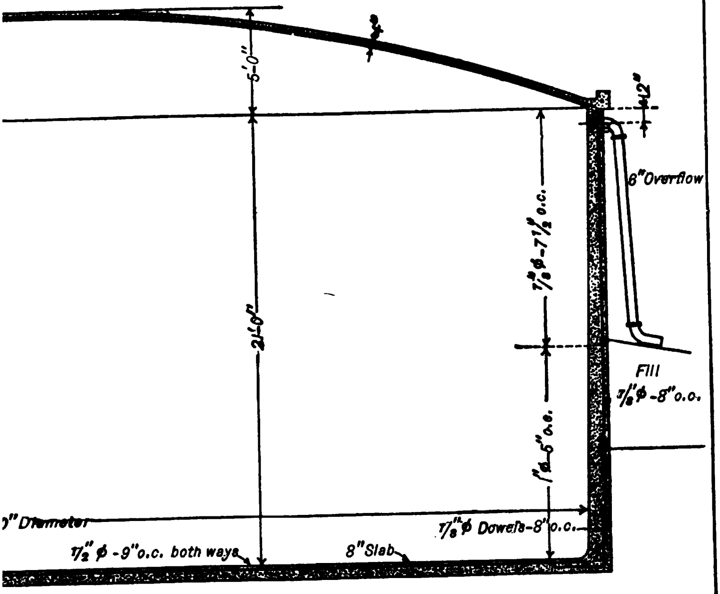


PLATE X

* Eng'g and Cont'g,



WATER TANK

E XIX.*

r'g, Jan. 22, 1913, p. 110.

Prob. 173*a*. What per cent of steel is used for reinforcement in each direction of the base slot of the tank shown in Plate XIX?

Solution. $\frac{1}{2}''\varnothing$ rods have a cross-sectional area of 0.196 square inch. Each foot width of slab has $\frac{12}{9}$ rods = 1.33 rods.

$\therefore$ Steel area/foot width = $0.196 \times 1.33 = 0.26$ square inch.

The area of concrete in 1 foot of width is $8 \times 12 = 96$ square inches.

$$\text{Per cent of steel} = \frac{0.26}{96} \times 100 \text{ per cent} = 0.27 \text{ per cent.}$$

Prob. 173*b*. What per cent of vertical reinforcement is used in the walls?

Prob. 173*c*. What is the per cent of annular reinforcement at the bottom of the tank? At the top?

Prob. 173*d*. What per cent of reinforcement is used in the roof of the tank?

Prob. 173*e*. Make a steel schedule for the tank. What is the tonnage?

Prob. 173*f*. How many cubic yards of concrete in the tank? What is the capacity of the tank? How many yards of concrete per 1000 gallons? How many pounds of steel per 1000 gallons?

174. Waterproofing. The importance of keeping tanks for the storage of liquids **watertight** is a parallel to the importance of keeping water from seeping through concrete into cellars, chambers, subways, and the like. Leaks not only defeat the purpose of the wall, but cause deterioration of the concrete itself. **Porous concrete,** as already mentioned, **is responsible for efflorescence and unsightly walls,** and allows the entrance of sea water, alkalies, and frost, all items of extreme importance in securing the permanence of the structure.

The general classification of waterproofing methods is shown in Table XXV, taken from the Booklet on **Structural Waterproofing** published by the **Truscon Laboratories.**

Table XXV

CLASSIFICATION OF THE GENERAL SUBJECTS OF WATERPROOFING AND DAMPPROOFING

Protection of Structural Materials Against Disintegrating Action of Water
- Dampproofing
  - *A*–Transparent Coatings and Treatments
    - (1) Sylvester Process
    - (2) Hot Paraffins and Waxes
    - (3) Special Proprietary Products
  - *B*–Opaque Decorative Coatings
    - (1) Various Cement Washes
    - (2) Common Oil Coatings
    - (3) Special Proprietary Cement Coatings
  - *C*–Special Bituminous Coatings
- Waterproofing
  - *A*–Integral
    - (1) Finely powdered dry compounds mixed with dry cement
      - (*a*) Repellent
      - (*b*) Non-repellent
      - (*c*) Metallic
    - (2) Compounds either in liquid or paste form added to water used to temper concrete
      - (*a*) Unsaturated Colloids
      - (*b*) Extended Colloids
      - (*c*) Concentrated Colloids
  - *B*–Membrane
    - (1) Coal Tar Pitch
    - (2) Natural Asphalts
    - (3) Special Bituminous Compositions

175. Filling Pores of Concrete. So much concrete is poorly proportioned, and so poorly controlled in making, that other materials are used to close up the pores of this poor concrete. It may be cheaper to make the good concrete than to use the remedies. Some of these substances are:

1. Substances added to the mixing water which act with the lime of the cement to form soaps; soap solutions that grease the concrete and act with the cement to form an insoluble compound to fill the pores.
2. Dry powders added to the cement, such as patent waterproofing compounds; mixtures of soap and alum; and hydrated lime. Hydrated lime equal to 10 per cent of the cement is recommended.*
3. Finely divided clay in an amount equal to about 5 per cent of the sand.

---

* Patent **Integral Waterproofing Compounds** are claimed to overcome the capillarity of concrete and to repel the water that seeks entrance.

176. Surface Treatment. When cracks occur through the concrete, because of shrinkage, or construction joints that are not properly made, the integral methods will not prevent seepage. When porous concrete is placed, it is afterwards rendered more water-resistant by surface coatings. These are **generally** not very effective, although some have been very successful.

In doing this work care must be taken with the surface to be coated. It must first be **cleaned,** and it must be **dry.** If the pores are small **Sylvester's wash of soap and alum** may be used. This is done by applying an alum solution of two ounces per gallon with a stiff brush, and immediately afterward a soap solution of three-quarters of a pound of castile soap per gallon is applied hot. Both washes are kept at a temperature of about 100° F. If the pores are larger, **hot paraffin is rubbed into the surface** of the concrete, previously heated. The paraffin may be applied cold if it is dissolved in some volatile solution like naphtha. Another common surface treatment is to **apply** some bituminous substance such **as tar or asphalt** to the dry surface, on the side of the wall or unit which is subjected directly to the water or moisture. Often a **plaster coat of rich mortar is applied.** This is good as long as the plaster continues to stay in place, but it is likely to crack under shrinkage.

177. Waterproofing with Membrane. The most expensive but yet the most positive method of waterproofing is the one where a pliable and continuous sheet of waterproofing material is laid over the surface on which the water pressure comes. The membrane is laid in several layers and is impregnated and bound together in the several layers with a bituminous compound.

The membranes used are:

Tarred felt
Asphalt felt
Burlap
Burlap saturated with asphalt and tar
Combination of canvas, felt and burlap.

The bituminous materials are:

Coal tar pitch applied hot
Asphalts applied hot
Asphalt mastic applied hot
Asphalt compounds with trade names.

A brick course laid in joints of mastic is a good waterproofer and is commonly applied on the backs of arches to protect the layers of the membrane. These membranes are especially good where expansion joints must be kept watertight. The use of membranes demands care, skill, and a good organization to produce satisfactory results. Some of the essentials to be secured are:

A clean surface
A dry surface
Thoroughly set concrete
A slightly rough surface
All form ties and nails removed
A continuous membrane with good laps
Protection of the finished membrane from injury.

The number of layers required for various purposes is given in Table XXVI, taken from the studies of Mr. M. H. Lewis in his "Modern Methods of Waterproofing."

TABLE XXVI

LAYERS OF MEMBRANES FOR VARIOUS CONDITIONS

Material	Head of water							
	0	1	2	6	8	10	15	20
Coal tar and felt............	2	3	4	5	6	7	8	9
Commercial asphalt and felt.	2	3	4	5	6	7	8	9
Special felts and compounds.	1	2	3	4	5	6	7	8
Asphalt mastic, inches thick.	$\frac{1}{4}''$	$\frac{5}{8}''$	$\frac{5}{8}''$	$\frac{5}{8}''$	$\frac{3}{4}''$	$\frac{3}{4}''$	$\frac{3}{4}''$	$\frac{3}{4}''$

(*Perform Job No. 71, Vol. II.*)

178. Effects of Acids on Concrete. The action of acids, oils, and sewage upon concrete is best stated in the report of the Joint Committee given herewith:

"**Dense concrete** thoroughly hardened is **affected** appreciably only **by acids which seriously injure other materials.** Substances like **manure,** that contain acids, **may affect green concrete,** but do not affect concrete that is thoroughly hardened.

"**Concrete** is **unaffected by** such **mineral oils** as petroleum and ordinary engine oils. **Oils which contain fatty acids produce injurious effects,** forming compounds with the lime which may result in a disintegration of the concrete in contact with them."

179. Reinforcement of Tanks. The reinforcement of circular concrete tanks is based upon calculations of hydrostatic pressure (water pressure), and is detailed in connection with plans prepared for these constructions. It is of value to the student, however, to have a simple guide for small tanks such as the one shown on Plate XIX, and Table XXVII as published from the records of the Portland Cement Association below:

TABLE XXVII

REINFORCEMENT FOR SMALL CONCRETE TANKS

(1) Depth	(2) Diameter	(3) Thickness of concrete in wall	(4) Diameter of horizontal rods	(5) Spacing horizontal rods at bottom	(6) Spacing horizontal rods at top	(7) Diameter vertical rods	(8) Spacing vertical rods
Feet	Feet	Inches	Inches	Inches	Inches	Inches	Inches
5	5	6	¼	8	18	¼	36
5	10	6	¼	6	12	¼	30
10	10	8	⅜	6	18	⅜	36
10	15	9	⅜	4	18	⅜	36
15	10	10	⅜	4	18	⅜	30
15	15	12	½	6	20	⅜	30

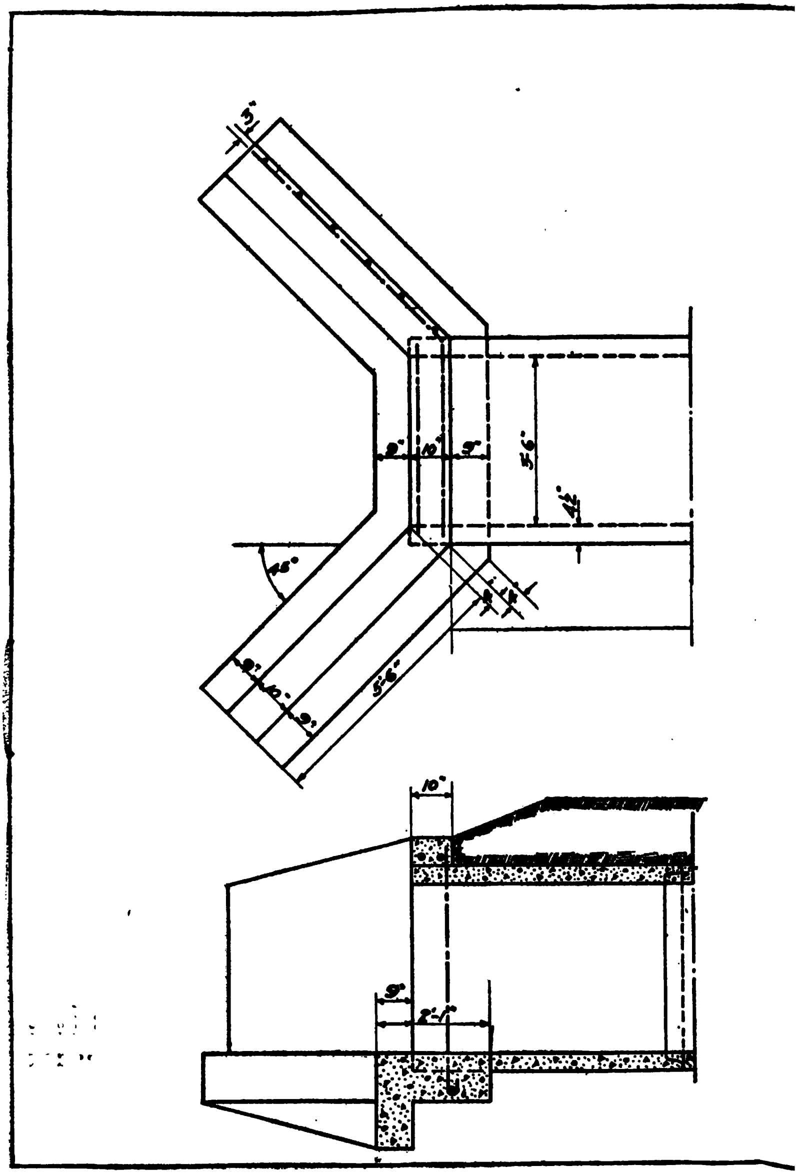
180. Concrete Culverts. The culvert has been devised in order to insure cross drainage for small ditches and creeks under roadways. Plate XX shows the plan for a small roadway culvert of this type based upon the specifications of the Iowa Highway Commission. The principles of construction involved in this phase of concrete construction have been covered elsewhere, and the student should study the application of them to Plate XX.

Prob. 180*a*. Make a steel schedule for one wing-wall abutment of the culvert shown on Plate XX. What tonnage do you get?

Prob. 180*b*. Calculate the yardage of concrete in one wing wall abutment.

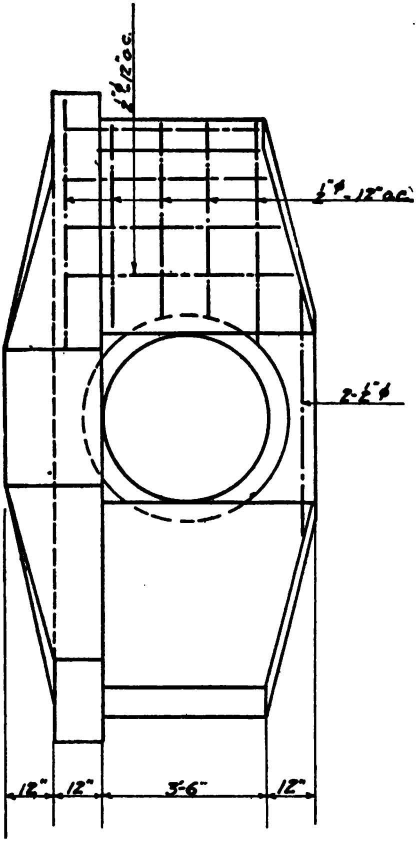
181. Depositing Concrete through Water. One of the conditions which the erection of a culvert may include is that of the **deposition of concrete through water.** Wherever possible, it is advisable to make the forms watertight and to deposit the concrete dry, but where this cannot be done special methods must be used.

The concrete may be **deposited through a** tube, called a **tremie,** by means of a bucket with a hinged bottom, or in **large cloth, jute, or paper bags.** The tremie is a tube about one foot in diameter at the top and flares slightly at the bottom. The bottom of the tube is kept at the bottom of the form, and the mixed concrete is poured in at the top of the tube. It finds its way to the place of deposit while the tube is lifted gradually to allow the concrete to leave, and is moved slowly about. The bottom must not leave the pile of freshly deposited concrete, allowing the water to enter. The tube must be kept full of concrete. When interruption has occurred and it is necessary to deposit concrete through water on a hardened surface, the latter should be washed free from scum. The use of buckets is more expensive and is less satisfactory, the work being accomplished in much the same way as with the tremes. The concrete, when placed by deposition in bags, may be filled into the bags dry, but this is not recommended because the water may not reach all of the cement. Paper bags are not so good as cloth bags, for the



PLATE

* (From Report of Iowa



42" PIPE CULVERT
FOR 10'-0" ROADWAY

E XX. *
a Highway Commission.)

cement can ooze through the cloth bags, uniting the whole by cementation. Sometimes blocks of concrete moulded near the site are hardened and deposited in place through the water.

182. Steel Girder and Concrete Slab Construction. A type of construction which is very ordinarily used in school and other such public buildings combines the concrete slab with structural steel girders and columns. This combination does away with considerable form centering and is conducive to greater speed in erection.

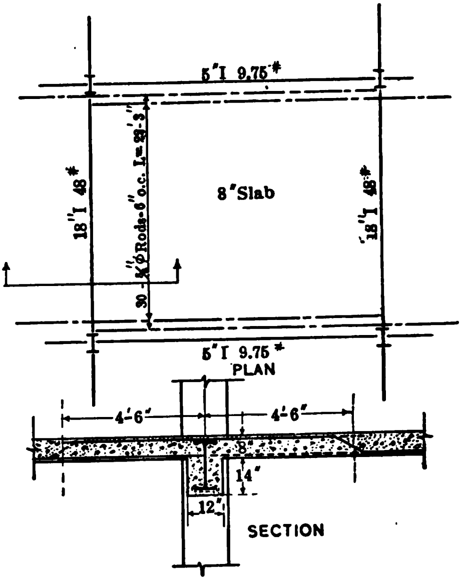


Fig. 196. Concrete Slabs for Structural Steel Frame.

Note the relation of the slab to the top of the steel and the method of indicating reinforcement and structural steel.

Fig. 196 shows the details of the framing of a floor panel in this sort of construction. The student is expected to study the form construction, placing of slab steel and the protection of the structural steel. It is unnecessary to go into any more detail on this, and the student is referred to the standard works on structural steel for further study.

Prob. 182*a*. What is the steel area per foot of slab in Fig. 196? What is the per cent of steel?

Prob. 182*b*. What is the tonnage of reinforcing steel in one panel as shown? What is the weight of reinforcing steel per square foot of floor slab?

Prob. 182*c*. How many pounds of structural steel per panel? (Beams and girders.) What is the weight of the structural steel per square foot of slab?

Prob. 182*d*. Make a plan and assembly cross-section of forms for this panel to ½-inch scale.

CHAPTER XIII

ESTIMATING

183. General Considerations. It is not the intention to make this chapter a treatise on estimating, but rather to acquaint the student briefly with the general principles underlying **quantity surveys** so that he may be able to launch out upon similar problems charged with some definite idea of **how to begin.** The field of estimating appeals to the ordinary layman as a hazy, uncertain, wonderful thing. He wonders how the prices for enormous projects can be so nearly predetermined. The ability to estimate costs accurately is indeed an accomplishment, and doubly so nowadays when one considers the variation in prices, labor turnout, and the new phases of construction.

Two general types of contract are recognized in the **letting of jobs,** namely, the **lump sum** and the **cost plus.** In the former the contractor must state a definite value for which he will construct the building in question. The latter is handled in two ways. Often the amount over and above the cost of the job is a fixed sum for profit, and at other times this amount of profit is a percentage of the cost. The first of these two methods is termed the **cost plus fixed sum** and the last the **cost plus per cent.**

These two contract schemes have much in their favor and disfavor. The opponents of the lump sum contract are generally contractors. Their claim is that it is impossible to estimate exactly what a building will cost due to the **uncertainty of material prices** and to the **unknown efficiency of labor.** They contend that the contractor who usually gets the work is the one who has omitted some part of the work by mistake, thereby unconsciously placing the others at a disadvantage. He, in order to cover his possible loss, must slight some part of the work, or if he is possessed of a good reputation in the community he becomes the loser. The opponents of the cost plus scheme are usually the owners. They contend that the contractor is desirous of **keeping** the **cost** of the building **high** so that his profit will be proportionately higher. They say that under such a contract the builder does not try to buy economically because there is no incentive for his doing so.

Under the **cost plus** scheme, however, by selecting a good builder and one who has the reputation of dealing fairly with his clients, the owner can rest assured that he will get the advantage of the best prices on labor and materials and he need have no concern that the builder will be tempted to slight any part of the building. The usual method used in protecting the rights of both the owner and the contractor is to have the builder make an outside figure for the building and to state a definite fixed sum for profit, provided the owner does not make any large changes during the process of construction. The reliable contractor then submits estimates for comparison from time to time and the owner is conversant at all times with the cost of his building. The other **big advantage** of the cost plus system **is that work can be started almost immediately** and the plans for the building can be developed parallel with the erection. This is a very distinct advantage in point of time.

184. Labor and Materials. To take off the quantity of materials necessary for a job is not such an enormous task, as it requires merely a **knowledge of construction and plan reading.** To determine the labor cost, however, involves the human element, which is extremely indeterminate. At times labor has limited its output on a building to one-half of what it was able to accomplish on another of equal size and intricacy. Then again conditions surrounding the building as to the site, ease of transportation, nearness to terminals and markets, and such items are often the cause of greater costs than one would ordinarily expect. The ability to soundly **judge all** these **conditions, combining them with modern plant and equipment,** has much to do with accurate cost surveys.

185. Three Estimating Divisions. The authors appreciate three distinct divisions in estimates; **quantities of stock materials required per unit of construction: the materials for assembling these** such as mortar, nails, etc.; and **the amount of labor required for each operation.** It is the intention to cover these items in connection with the erection of the building discussed in this text and then to allow the student to estimate the cost of it in comparison with the itemized estimate of the building prepared below:

Description	Notes	Quantity	Unit price	Totals
Concrete:				
Wall footings	1-3-6	20 cy.	$11.50	230
Retaining wall footings	1-2-4	16 cy.	11.50	208
Interior col. footings	1-2-4	4 cy.	13.00	52
Interior col. footings	1-3-6	.2 cy.	13.00	2
Foundation walls, plain	1-3-6	69 cy.	11.50	794
Retaining walls	1-2-4	31 cy.	13.00	403
Coal chute	1-3-6	2 cy.	11.50	23
Interior columns	1-2-4	3⅓ cy.	13.00	44
Slabs	1-2-4	81 cy.	13.00	1,053
Beams and lintels	1-2-4	17½ cy.	13.00	228
Skylight curb walls (Louvre)	1-2-4	3 cy.	13.00	39
Window sills	....	126 fl.	0.72	91
Door sills	....	5 fl.	0.80	4
Coping	....	178 fl.	0.72	129
Posts	....	42 fl.	0.85	36
Balusters	....	74 fl.	0.45	34
Rails	....	100 fl.	0.75	75
Stairs, reinforced	1-2-4	2 cy.	15.00	30
Stairs, plain	1-2-4	2 cy.	15.00	30
Paving	1-3-6	78 cy.	12.50	975
Curb and gutter	1-2-4	120 cf.	1.45	174
Granolithic finish	Integral	344 sf.	0.06	21
Granolithic finish	Separate	920 sf.	0.11	102
Machine bases	8″ thick	172 sf.	0.37	64
Forms:				
Walls	....	4,985 sf.	0.18	935
Columns	....	352 sf.	0.20½	73
Slabs	....	1,633 sf.	0.16½	270

Description	Notes	Quantity	Unit price	Totals
Beams and lintels		1,520 sf.	0.18½	282
Stairs		60 sf.	0.20½	13
Cinder concrete saddles		3 cy.	9.00	27
Carborundum rubbing		205 sf.	0.07½	16
Reinforcement		12,830 lbs.	0.04¼	546
Excavation		779 cy.	1.65	1,286
Backfill		108 cy.	40.45	49
Brickwork		2,800 cf.	0.80	2,240
Concrete block		84 sf.	0.32	27
4-inch tile partitions		1,344 sf.	0.22	296
Steel sash		618 sf.	0.35	217
Wood sash and doors		567 sf.	0.55	312
Wood stud partition and metal lath		504 sf.	0.50	252
Glass and glazing		1,100 sf.	0.25	275
Light iron work:				
1 Kinnear rolling shutter		1	125.00	125
1 chkd. pl. and fr. coal chute		1	15.00	15
1 Majestic ash door and frame		1	17.00	17
1 C.I.C.O. door and frame		1	3.00	3
48 fl. 5 × 4 × ¼ L lintels		410 lbs.	0.06	25
2-inch pipe posts		3	1.00	3
1½-inch pipe rails		20 fl.	0.27	6
Iron ladder		11 fl.	1.00	11
5-ply J. M. roofing		33 sqs.	22.00	726
3⅛-foot flashing J. M.		300 fl.	0.35	105
G.I. std. skylight 8′ × 12′		2	60.00	120
G.I. Louvre 5′ × 5′		1	50.00	50
Plastering on masonry		410 sy.	0.55	226
Plastering on metal lath		87 sy.	1.35	118
Linoleum		300 sf.	2.65	795
Creosoted wood block		2,542 sf.	0.22	560
Clean-up job and clean glass				150
Liability insurance	2%			300
Watchman, 5 weeks		5 wks.	30.00	150
Superintendence, overhead, etc		5 wks.	125.00	625
Sundries	2%			322
Profit	10%			1,641
Total Bid				$17,728
Omitted from estimate				
Heating				
Plumbing				
Lighting				
Painting				
Equipment				

186. Clearing the Site. The clearing of the site involves the question of **labor** and **transportation** almost entirely. The speed of operation depends upon the nature of the ground. If trees are encountered labor must be expended in their removal. A 16-inch tree requires the time of two laborers for about one and one-half days, while the ordinary tree can be removed by two laborers in one day. Underbrush can usually be removed from the average site in one day by two men. If the rubbish must be hauled, the number of loads must be determined and a team will dispose of a load on a two and one-half mile trip over average roads in about two and one-half hours. The team requires the time of a driver and laborers in this case and it is quite possible that a **dumping charge** of from ten to twenty-five cents may be made per load.

187. Loosening Materials. This item in the cost of a building must be determined in connection with borings and and the conditions surrounding the building. The following figures are given merely as a check.

1. One plow, team and driver and one helper will loosen 35 cubic yards of ordinary earth in one hour.
2. One plow, team and driver and one helper will loosen 15–20 cubic yards of dirt or clay per hour.
3. A pick pointed plow, four horses, two drivers and one helper will loosen 19 cubic yards of tough soil per hour.
4. A man with a pick will loosen:
    - 3½ yards of average earth per hour
    - 2 yards of tough clay
    - ¾ yard of hardpan.

188. Moving Materials. The movement of materials may be accomplished by wheelbarrows, carts, wagons, scrapers or industrial track cars. A laborer will load loose material by shoveling from the ground or car into a wagon as shown in Table XXVIII.

TABLE XXVIII

LOADING ACCOMPLISHED BY ONE LABORER

Materials and movement	Good conditions, no delays, cubic yards per hour	Inexperienced workmen and delays, cubic yards per hour
From car to wagons — stone	2.2	2.0
From car to wagons — gravel	2.7	2.0
From car to wagons — sand	3.5	2.5
From ground to wagons — plowed clay, some large pieces and stones	2.0	1.5
From ground to wagons — plowed loam	2.5	2.0
From ground to wagon — stone	3.0	2.0
From ground to wagon — sand	4.0	3.0

The movement of material depends upon **vehicular capacities** and these in turn depend upon the nature of the ground over which they are hauled. Table XXIX is a conservative estimate of the capacities of various carriers and will often be found useful in an analysis of working conditions in a plant.

TABLE XXIX

VEHICULAR CAPACITIES

	Cubic feet
Wheelbarrows	3–4
One-horse dump carts	18–22
Two-horse dump wagons	27–45
Drag scrapers	3–7
Wheel scrapers	10–17
Dump-car on rails	27–80

189. Hauling Charges. Hauling charges include the **cost of loading and unloading,** both **working and waiting time of the team and driver,** and the **team time in travel.** The less lost motion there is, by just so much can hauling charges be reduced. Rate of team travel is based usually on from

twenty to twenty-two miles actual distance **in ten hours over average roads and grades** with occasional bad spots. If there are difficult places en route two or more teams should be run together so that one can be used as a "**snatch**" team if the other gets stalled.

Dirt or clay when loosened will increase in volume from 20 to 35 per cent and go back in fill to its original volume if compacted to the same degree as in its natural condition. Earth will shrink as much as ten per cent of its original volume if transferred to another location and if compacted with a roller. (Check against Art. 13.)

A team will haul about two cubic yards on a good road, and about half that amount over excavated or soft ground. Sometimes it is necessary to use a "snatch" team to haul material economically.

A **yard of material** can be **loaded by a shovel gang** in about **six minutes.** As team time runs high it is often profitable to employ a loading device or extra wagons which can be run in place by a snatch team or laboring gang. The following information is based upon a six-minute loading time for one cubic yard of material:

Slat Wagons:

Load and dump — 8 minutes
Hitch, dump and unhitch — 4 minutes

Contractor's Dump Wagon:

Load and dump — 6 minutes
Hitch, dump and unhitch — 2 minutes.

Two thousand feet of travel will take ten minutes, giving a haul of 1000 feet. For each additional 1000 feet of loaded haul ten minutes should be added to the time en route.

TABLE XXX

HAULING CAPACITIES ON VARIOUS ROADS

A team will haul on	Pounds	Aggregate, cubic yards	Sacks cement	Excavation, cubic yards
Very poor earth road	2000	0.67	20	0.8
Poor earth road	2500	0.835	25	1.0
Good hard road	4000	1.33	40	1.6
Good macadam or paved road	6000	2.00	60	2.4

SUMMARY HAULING CHARGE

Labor time in loading........yards........hours at $... per hour.........

Loss of team time waiting or changing wagons........... minutes at $... per minute.

Team time consumed in unloading........minutes at $... per minute...... .

Labor time consumed in assisting unloading........minutes at $...per minute...... .

Team time........hours en route at $... per hour......

Total expense for hauling.... .yards to job.........

Cost per cubic yard for hauling to job........

Superintendence and overhead, 15 per cent........

TABLE XXXI

AVERAGE OUTPUT FOR TWO LABORERS PER DAY LOADING AND WHEELING

	Cubic yards.
Ordinary soil	12
Loam	6
Stiff clay	4

The output of labor depends very much upon the plant used and this is determined by the economical haul for various units. J. C. Trautwine gives the economical haul for **drag scrapers as 150 feet**; for **wheel scrapers as 500 feet**; for **one-horse dump-cart as 600 feet**; and **for wheelbarrows as 250 feet.**

190. Hauling Cement. A team will haul the loads itemized in Table XXX at ten minutes per 1000 feet of loaded haul. Loading near the stock pile takes about **three-quarters of a minute of labor per sack of cement** or about three minutes per barrel. **Unloading** under similar conditions takes the **same amount** of time. The time that a team is delayed in doing this is dependent upon the number of laborers employed. It may therefore be profitable to have additional wagons at one or both ends of the haul, so that the teams will not be delayed. The **time consumed** in **changing wagons twice** may be taken as **about five minutes.** To the net cost of cement when handled in sacks there should be added a charge of **ten cents per barrel to cover the handling of empty sacks,** shipping them back and the loss of sacks which cannot be redeemed.

191. Concrete Work. All **units** of concrete work are **based upon the yardage of concrete in place.** This involves a volumetric determination of all the members in the structure. The cubical contents of footings, columns, walls, slabs and beams are kept separate so that they may be separately priced.

192. Cement. Cement can be estimated accurately; therefore it is not necessary to increase the quantity estimated for. There should, however, be something added to the actual cost of the cement per barrel to cover the cost of handling the sacks. The percentage of sacks lost is largely dependent upon the way in which they are handled on the job. It is safe to say that the average loss amounts to about ten cents per barrel in sacks, labor of handling them and of accounting for them. This includes return freight.

193. Aggregates. Aggregates are **sold by weight or by the yard.** A unit weight is adopted and orders received in cubic yards are converted into equivalent weight. The unit weight is often adopted by agreement, so that the volume may be only approximately correct. If aggregates are hauled a considerable distance and transferred from railroad cars to wagons there will be some loss in weight and some actual loss on the job because of materials becoming mixed with or tramped into the dirt. **Losses can generally** be figured as **not to exceed 10 per cent** for each class of aggregate.

194. Water. Often contractors fail to include the cost of water in estimating. Sometimes it costs comparatively nothing, but frequently its cost is considerable. The quantity of water required can be safely figured as amounting to from **40 to 60 gallons per cubic yard for concrete only.** In addition, however, water required for operating mixers, engines, wetting forms, sprinkling concrete, sprinkling sub-grade in pavement work, etc., will increase the quantity required to **100 gallons per cubic yard.** For **mass concrete 60 to 75 gallons per cubic yard** is a safe estimate. For **slab floors, sidewalks** and **pavements** from **125 to 165 gallons** may be required, depending upon the season of the year. Water may have to be hauled or piped a considerable distance. Often water can be contracted for from the city water mains. In such cases charges are frequently based upon a rate of from **one-half to one and one-half cents per square yard** of concrete pavement.

Table XXXII

MATERIAL AND LABOR FOR SETTING FORMS

Member	Board feet per square foot form.	Nails or bolts, pounds per square foot	Square feet per man per day.
Floorings and foundation beams	1.58	0.008	85
Partitions and walls	2.30	0.110	85
Wall beams	1.85	0.010	100
Floor beams and girders	6.10	0.010	75
Rectangular columns	2.10	0.006	85
Beam and girder slab — 5′ 0″ span	2.15	0.008	120
Beam and girder slab — 7′ 0″ span	2.15	0.008	150
Beam and girder slab — 9′ 0″ span	2.15	0.008	200
Flat slab construction	2.00	0.008	300

195. Forms. Forms are usually **estimated by the square foot of surface set.** A reasonable estimate of materials and labor is given in Table XXXII.

In addition to the labor of erection is the labor of unloading and carting the lumber. A fair estimate for these two items allows about 2500 board feet per laborer per day for the former and about 1200 feet per laborer per day for the latter.

196. Reinforcement. The taking off of reinforcement from design details is a simple matter provided the estimator is thoroughly familiar with such plans. The student should possess sufficient plan-reading ability at this stage to make such a take-off, and if he arranges his take-off as shown in Table XIII, Chapter V, he will have no trouble in obtaining a definite and thorough classification of his steel. For purposes of further developing the take-off sheet for reinforcement, Table XXXIII is given below:

Table XXXIII

TAKE-OFF SHEET FOR REINFORCEMENT

1	2	3	4	5									
Size of Rod	No. of Pcs.	Length	Bends	⅜		½		⅝		¾		1	
				Lin. feet	Bends	Lin. feet	Bends	Lin. feet	Bends	Lin feet	Bends	Lin. feet	Bends
Totals													
Summary													

TABLE XXXIII (*Continued*)

Size	Unit weight	Total weight	Size extra	Number bends	Hours for bending
$\frac{3}{8}$					
$\frac{1}{2}$					
$\frac{5}{8}$					
$\frac{3}{4}$					
$\frac{7}{8}$					
1					
Total					

Tonnage Extra = 2000 x
Length extras =

As in Table XIII, Table XXXIII gives the size, number of pieces, length and the bending of all rods. The person extending, carries these items into column five and fills in the summary table. The labor for bending is a variable and is at best only an approximate figure. Two laborers with a competent foreman can execute thirty bends per hour by hand, and with a machine a foreman and one laborer can accomplish about twice that amount. It would be of inestimable value for the student to visit jobs where bending is being done both ways and to **make time studies** on the work.

197. Mixing and Placing Concrete. The mixing and placing of concrete can be done as given in the time table given below:

1. Mixing by hand — 0.2 yards per man per hour.
2. Stationary mixer on elevated loading platform, wheeling a short distance to the mixer — $\frac{2}{3}$ yard per man supplying material to the mixer and operating the mixer.
3. Movable mixer with mechanical loading skip — 1 to $1\frac{1}{4}$ yards per man per hour supplying material to the mixer and operating the mixer.

Certain amounts of **quaky** consistency concrete will slop over from the wheelbarrows on level to average grades from the mixer to the place of deposition. The following information gives the amount of concrete including this item that can be placed from the mixer and includes the time required for spreading and spading.

25 foot haul — 0.75 cubic yards per man per hour
100 " — 0.50 " " "
150 " — 0.40 " " "
200 " — 0.33 " " "
225 " — 0.30 " " "

The above estimates are safe where the crew is balanced so that no portion of the work is delayed.

When the mixer can be kept close to the place where the concrete is being deposited the only labor required is that to spread the concrete. One man can handle up to 2.5 yards per hour; two men can generally do more than twice that done by one man, and four men can handle from 12 to 16 yards per hour, depending upon the nature of the work.

When concrete must be hoisted above the level of the mixer the problem is simple to solve; it is difficult, however, to give any cost data because of the variation in character of plants and the many different heights to which the concrete is raised. The plant, however, when once chosen remains constant in daily operating cost while the output is dependent upon the time of operation.

For example: A one-horse operated winch is used to hoist concrete for silo work. The quantity of concrete deposited each day must be the same, as the forms must be filled once each day. As the height of hoist increases, the time consumed in raising the hoist bucket of concrete increases; the horse must work more hours to raise the same amount of concrete and the time of the gang is lengthened accordingly. Even with the engine hoist the same results follow.

When the quantity of concrete to be deposited in a given period is variable, the cost will vary unless the size of the gang is kept adjusted to working conditions.

Several types of ordinary **elevator hoists** are available. Their **output** may be **estimated by dividing one-fourth the loaded speed in feet per minute into the height to which it is operating.** There is also an endless chain hoist with lugs which catch the barrow or wheel carts, carry them to the required height, automatically set them off, and return the empty ones in the same manner. With this equipment the output may be maintained constant by adjusting the number of carts or barrows; then the cost of raising the concrete would be the cost of operating the hoist together with the accessories.

Concrete is sometimes delivered by **gravity spouts or chutes,** but here the hoist problem is the same, and the spout substitutes the conveying of concrete by barrows or carts from the elevator to the place of deposition.

(Perform Jobs No. 130 and 131, Vol. II.)

198. Cost of Concrete per Yard in Place. This is a valuable piece of cost data for use in designing rooms and for rapid estimates. The following discussion on concrete is taken from "**Economy in the Design of Reinforced Concrete Buildings,**" by **Clayton W. Mayers of the Aberthaw Construction Company** and is well worth the student's time and study. (Based on 1918 prices.)

"In estimating the cost of concrete it is necessary first to ascertain the cost, delivered at the job, of cement per barrel, sand per cubic yard, and crushed stone per ton. Knowing these costs it is a simple matter to calculate the total cost of the materials which go to make a cubic yard of concrete. Add to this cost of materials the proportionate cost of "plant" and the cost of mixing and placing one cubic yard of concrete, and we have the estimated unit cost of one cubic yard of concrete in place. The following tabulation is a detailed estimate of the cost of concrete mixed in the proportion of 1 : 2 : 4.

Concrete (1 : 2 : 4 mix), per cubic yard:		
Cement, $1\frac{2}{3}$ bbls. at $2 per bbl. at the job		$3.33
Sand, ½ cubic yard at $1.50 per cubic yard at the job,		0.75
Crushed stone, $1\frac{3}{10}$ tons at $2 per ton at the job		2.60
Plant, cost per cubic yard?		
Freight charges	$0.05	
Rental of mixer, etc	.35	
Small purchases, fuel and supplies	.45	
Labor	.40	
		1.25
Labor of mixing and placing		1.25
Total cost per cubic yard		$9.18
Total cost per cubic foot		0.34

Concrete mixed in the proportion of **1 : $1\frac{1}{2}$: 3** will require about one-third of a barrel more cement per cubic yard. This will add about 67 cents to the cost of one yard of concrete in place, making the unit price about $9.85 per cubic yard, or **$36\frac{1}{2}$** cents per cubic foot. If a 1 : 1 : 2 mix of concrete is used, the cement will be increased about $1\frac{2}{10}$ bbls. over and above that used in a 1 : 2 : 4 mix. At $2 per bbl. this would make the cost of **1 : 1 : 2** mix concrete about $11.58 per cu. yd., or **43** cents per cu. ft. In large plain concrete footings it is sometimes advisable to use a concrete mixed in the proportion of 1 : $2\frac{1}{2}$: 5. Concrete mixed in this proportion requires about $\frac{3}{10}$ of a barrel less cement than 1 : 2 : 4 mix. Figuring cement at $2 per bbl., concrete mixed in the proportion of **1 : $2\frac{1}{2}$: 5** works out at approximately **32** cents per cu. ft. in place.

In calculating the amount of materials necessary to make 1 cu. yd. of concrete, it will be noticed that the only change made in the quantities for the various mixes has been in the amount of cement used. It has been assumed that a cu. yd. of 1 : 1 : 2 concrete will require the same quantity of sand and crushed stone as a cu. yd. of 1 : 2 : 4 concrete. Theoretically this is not true, but in general practice there is some waste of material and it has been found that the small differences of aggregate used in the various mixes of concrete in a building are negligible. A very large part of the concrete in a building is a 1 : 2 : 4 concrete; therefore, the aggregate quantities of 1 : 2 : 4 mix are generally used for all concrete work and the cement alone is changed for various mixes. It will also be noted that the quantity of cement, sand and stone used here is somewhat in excess of the amount usually given in the tables published in various text-books. It must be borne in mind that the waste of materials on the job must be absorbed and the quantities in tables compiled by laboratory tests must be somewhat increased. It is actually necessary to estimate on about 1⅔ bbls. of cement to make 1 cu. yd. of 1 : 2 : 4 concrete on a job where the usual construction methods are employed and in other mixes of concrete the cement should be proportionately increased.

The prices of concrete work as tabulated here are about 30 per cent in excess of pre-war prices and 50 per cent more than the prices of 1913. These costs based on the present high cost of material and labor should be adjusted from time to time as necessary."

199. Brickwork. The ordinary practice in taking off brickwork is to obtain the **cubic feet of brickwork** in the entire building, or to determine the number of **square feet of various thicknesses of walls.** The number of brick allowed per cubic foot can be safely placed at 19 for common work, but if the brick are to be **culled or picked over** for facing brick an **allowance** of about **50 per cent** is made. Generally an allowance of 10 per cent will take care of cutting and poor brick. Openings of less than 80 square feet are disregarded in the estimate and openings of more than 80 square feet are figured 2 feet narrower than shown. Piers or breasts are figured as wide as twice the projection plus the face and as thick as the pier or breast. Chimneys and ducts are always estimated solid.

The mortar for brickwork is usually based upon a **1 : 3 mixture** and is made up of one part of cement to three parts of sand with an addition of 15 per cent of lime paste. A cask of lump lime (2.5 cu. ft.) will make about 6.25 cubic feet of lime paste when slaked. The percentages of mortar required for brickwork are about 35 to 40 per cent for ½ to ⅝ inch joints and about 25 to 30 per cent for ¼ to ⅜ inch joints. Pressed bricks with ⅛ inch joints require only 10 to 15 per cent.

Bricks are sold by the thousand, lime by the ton — **a cask weighing about 100 pounds,** cement by the barrel — **four bags,** and sand by the ton or cubic yard. Table XXXIV gives the materials required for various mortars taken from Taylor and Thompson's Concrete, Plain and Reinforced, p. 213.

TABLE XXXIV

QUANTITIES OF MATERIALS FOR VARIOUS MIXES OF MORTAR

Proportion by parts		Ordinary coarse sand		Very fine sand	
		Materials for 1 yard of plastic mortar		Materials for 1 yard of plastic mortar	
Cement	Sand	Packed cement, barrels	Loose sand	Packed cement, barrels	Loose sand
1	2	4.88	0.72	4.48	0.66
1	2	3.21	0.95	3.02	0.90
1	3	2.39	1.06	2.28	1.01
1	4	1.90	1.13	1.83	1.08
1	5	1.58	1.17	1.53	1.13

The addition of lime for workability is usually about 15 per cent by volume of the cement or 1.43 cubic feet of lime putty per yard of 1–3 mortar. To summarize this information, 1000 brick will lay up in a 1–3 mortar with ⅜ inch joints by the use of 1.4 barrels of cement, 0.62 yard of sand and 0.84 cubic foot of lime putty. A 100 pound cask of lime will therefore lay up about 7500 bricks.

The labor for bricklaying is another variable factor and can only be determined after experience with one's steady employees. A good bricklayer should lay 1000 brick in an

8 hour day and each mason requires the services of 1¼ laborers. If the contractor is forced to use unknown labor he is far wiser to estimate only 750 brick per day per man.

200. Tile. The partitions in most industrial buildings are either of tile or of brick. This tile may be the ordinary structural terra-cotta or some form of gypsum block. One tile is usually estimated as covering one square foot of superficial area. The same rule regarding openings holds for tile as for brick. The estimator then should add about **15 per cent for breakage and cutting.**

A good tile setter should place about 100 blocks per day using about one-third to one-half of the mortar required for a like volume of brickwork. His requirement for laborers is the same as for the brick mason. If lathed-tile joints are to be used allow about 1 foot of strip-mesh per tile, cutting to a ten per cent waste.

201. Rough Framing. The best method for estimating framing is to make an accurate take-off from prepared framing plans, allowing each piece a length equal to the next even foot over the actual length required. **All lumber,** generally speaking, is **sold by the board foot,** and the whole estimate should be extended into the number of board feet of each of the various sizes of lumber required.

The labor required can be based upon Table XXXV.

TABLE XXXV *

Framing Stuff (Hours required to place 1 M.)

PLACING LUMBER OF VARIOUS SIZES AND KINDS

2″ × 3″ studs require 35 hours to place 1 M.
2″ × 4″ and 2″ × 6″ studs require 32 hours to place 1 M.
2″ × 8″ studs require 30 hours to place 1 M.
1″ × 1″ grounds require 83 hours to place 1 M.

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* By Emery Stanford Hall, B.S. From the "Handbook for Architects and Builders," published under the auspices of the Illinois Society of Architects.

1″ × 2″ grounds and furring require 64 hours to place 1 M.
2″ × 2″ grounds and furring require 50 hours to place 1 M.
1″ × 8″ to 10″ sheathing require 30 hours to place 1 M.
1″ × 4″ roof sheathing or slats require 26 hours to place 1 M.
1″ × 6″ roof sheathing or slats require 26 hours to place 1 M.
Shingles laid 4½″ to W. require 5.8 hours to place 1 M.
1,000 sq. ft. paper or felt require ¾ hour to place 1 M.
1″ × 8″ and 1″ × 6″ D. & M. sheathing require 25 hours to place 1 M.
1″ × 4″ D. & M. sheathing require 26 hours to place 1 M.
2″ × 4″ and 2″ × 6″ D. & M. sheathing require 20 hours to place 1 M.
3″ × 4″ D. & M. sheathing require 14 hours to place 1 M.
3″ × 6″, 3″ × 8″, 4″ × 4″ and 4″ × 6″ D. & M. sheathing require 16.6 hours to place 1 M.
4″ × 8″ D. & M. sheathing require 15 hours to place 1 M.
1″ × 1½″ and 1″ × 2″ D. & M. hardwood flooring require 66 hours to place 1 M.
1″ × 3″ D. & M. hardwood flooring require 58 hours to place 1 M.
1″ × 4″ D. & M. hardwood flooring require 53 hours to place 1 M.
1¼″ × 2″ D. & M. hardwood flooring require 63 hours to place 1 M.
1¼″ × 3″ D. & M. hardwood flooring require 60 hours to place 1 M.
2″ × 4″ and 2″ × 6″ rafters require 33 hours to place 1 M bd. ft.
2″ × 8″ rafters require 30 hours to place 1 M bd. ft.
2″ × 6″ and 2″ × 8″ joists require 25 hours to place 1 M bd. ft.
2″ × 10″ joists require 21.5 hours to place 1 M bd. ft.
2″ × 12″ and 2″ × 14″ joists require 20 hours to place 1 M bd. ft.
3″ × 8″ and 3″ × 10″ joists require 20 hours to place 1 M bd. ft.
3″ × 12″, 3″ × 14″ and 3″ × 16″ joists require 18 hours to place 1 M bd. ft.
4″ × 8″ and 4″ × 10″ joists require 20 hours to place 1 M bd. ft.
4″ × 12″ and 4″ × 14″ joists require 18.7 hours to place 1 M bd ft.
4″ × 16″ joists require 16.7 hours to place 1 M bd. ft.
6″ × 6″ joists require 20 hours to place 1 M bd. ft.
6″ × 8″ and 6″ × 10″ joists require 18.7 hours to place 1 M bd. ft.
6″ × 12″ and all stuff up to 16″ × 16″ for joists require 16.7 hours to place 1 M.
4″ × 4″ posts require 23 hours to place 1 M bd. ft.
6″ × 6″ posts require 20 hours to place 1 M bd. ft.
8″ × 8″ posts require 18 hours to place 1 M bd. ft.
10″ × 10″, 12″ × 12″, 14″ × 14″ and 16″ × 16″ posts require 16.7 hours to place 1 M bd. ft.

TRIM OR FINISH

It is impossible to give any accurate idea of the amount of time required to do this class of work, there are so many conditions that enter into consideration that cannot be stipulated in a table.

Openings require in labor to put in blocks, set jambs or frames, place trim, hang doors or windows and put on hardware from 6 to 12 hours, but average in all sorts of work and buildings about 9 hours.

Baseboard, one member, 1000 linear feet requires 50 hours to place.

Baseboard, two members, 1000 linear feet requires 66 hours to place.

Baseboard, three members, 1000 linear feet requires 83 hours to place.

Plate-shelf, 3 part, consisting of shelf, apron and mould, 1000 linear feet requires 100 hours to place; add 1–6 hours for each bracket.

202. Wall Coverings. Due to the **matching** and **special lengths** required for wall and floor coverings in order that **joints** may be **broken** or **lapped,** more material is used in this work than the exact area of wall or floor would indicate. Table XXXVI gives the constant by which the surface to be covered must be multiplied to obtain the number of board feet of lumber required.

TABLE XXXVI *

CONSTANTS FOR WALL COVERINGS

$W = 1$ for plain boards laid close.
$W = 0.65$ for 1″ × 4″ battens placed 6″ from c.
$W = 0.75$ for 1″ × 6″ battens placed 8″ from c.
$W = 1.13$ for 6″ to 8″ D. and M. flooring or sheathing.
$W = 1.19$ for 4″ D. and M. flooring or ceiling.
$W = 1.25$ for 3″ D. and M. flooring or ceiling.
$W = 1.34$ for 2″ D. and M. flooring.
$W = 1.75$ for 1½″ D. and M. flooring.
$W = 1.30$ for 6″ siding 4¼ to weather.
$W = 1.38$ for 4″ siding 2½ to weather.
$W = 1$ for most felts and papers as these are usually listed for enough less than the roll actually contains to allow for lapping.

* See footnote, p. 345.

203. Nails. The item of nails is usually slighted in many cases. This is either done by allowing a lump sum for nails without a **"check take-off"** or by allowing the cost of nails to come under the head of **extras.** Table XXXVII is the one commonly used and seen for this work, and it is worth the builder's study in order that he may estimate his nails as carefully as his lumber. (See also Table XIII.)

TABLE XXXVII *

NAILS REQUIRED FOR DIFFERENT KINDS OF WORK

For 1000 shingles 3½ to 5 lbs. *4d.* nails, or 3 to 3½ lbs. *3d.*
For 1000 laths, about 7 lbs. *3d.* fine.
For 1000 feet clapboards, about 18 lbs. *6d.* box.
For 1000 feet covering boards, about 20 lbs. *8d.* common, or 25 lbs. *10d.*
For 1000 feet upper floors, square edged, about 38 lbs. *10d.* floor, or 41 lbs. *12d.* floor.
For 1000 feet upper floors, matched and blind-nailed, 38 lbs. *10d.* or 42 lbs. *12d.* common.
For 1000 feet partitions, studs or studding, 1 lb. *10d.* common.
For 1000 feet furring, 1 × 3, about 45 lbs. *10d.* common.
For 1000 feet furring, 1 × 2, about 65 lbs. *10d.* common.
For 1000 feet pine finish, about 30 lbs. *8d.* finish.

204. Plastering. The materials for plastering depend upon the type of work to be done. Four types of such work are here considered and the quantities given. Further study of other finishes will enable the student to enlarge upon his fund of information on plaster work.

205. Concrete Pavements. The materials for pavements can best be estimated by determining the **number of square feet of walk or road to be placed.** The cinders can then be estimated by allowing ½ cubic foot per square foot of pavement. The concrete being a 1–2½–5 mix can be reduced to cement, sand, and stone by a reference to Table III, Chapter

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* By Emery Stanford Hall, B.S. From the "Handbook for Architects and Builders," published under the auspices of the Illinois Society of Architects.

TABLE XXXVIII

MATERIALS AND LABOR FOR PLASTER WORK

100 Square Yards

Labor and materials	3-coat on wood lath	2-coat sand finish	2-coat on brick or tile	Hard wall plaster, metal lath
Lath.........	1500	1500	....	105 sq. yds.
Nails......... (3d fine.)	10#—16"o.c. 13#—12"o.c.	Same as 3 coat	....	....
Staples.......	....	....	....	$\frac{3}{4}$"— 9#
Lime.........	12 bu.	12 bu.	10 bu.	1 bu.
Sand.........	1½ yds.	2 yds.	1½ yds.	2 yds.
Hair.........	2 bu.	2 bu.	1 bu.	....
Plaster of Paris.......	100#	....	100#	100#
Lathers.......	10 hrs.	10 hrs.	....	8 hrs.
Plasterers....	16 hrs.	16 hrs.	12 hrs.	18 hrs.
Laborers......	20 hrs.	20 hrs.	15 hrs.	22 hrs.
Hard wall plaster	....	....	....	2000# 20 bags

III. The **finish** is usually **1 inch thick** and the materials for this can be estimated from Table XXXIV of this Chapter.

The labor for paving will vary with the size of the job and the number of angles and curves. The forming can be based upon the labor required for setting 2 × 4's as given in Table XXXVI. The placing and finishing of the concrete will take one finisher and four laborers 8 hours to complete about 400 square feet under ordinary circumstances. It is wise to establish a unit price per square foot after the first job is completed and then to use this value on later work.

206. Light Iron Work. The materials for this work are usually determined and priced by bids from steel men to the builder. The builder's province is the forming and setting only. The time required for such work is an extremely variable factor depending upon the bulk of the work and its weight. This can be worked out on the basis of the number of pieces or upon the tonnage basis. Heavy steel can be set at the rate of 1½ to 2 tons per man per day, if proper derrick facilities are provided. If the steel is light as in this building the authors doubt if more than 0.15 ton per man per day can be disposed of. The inserts for such work as this building entails can be placed at the rate of 100 per day per carpenter. This may be unreasonably high if special fitting is required.

207. Sash, Frames, and Doors. These items come to the job ready for erection and a bid is made for their construction to the builder. A rough estimate can be made by the contractor by **taking off the number of frames and the gross area and then getting an "outside" quotation for both the wood and steel sash.**

The labor of placing the frames will depend upon the size, but the ordinary wood sash can be set, plumbed, and braced by two carpenters in about ½ hour. The steel sash is set and blocked in place more rapidly as the jamb and head grooves assist in plumbing. The care exercised is in relation to the blocking and aligning of the sash. Two men can set about twenty steel sash per day.

Wood sash usually come to the job glazed, but the glazing of steel sash is done after the sash are in place. The contractor should take off the number of lights of clear sheet, ribbed, and wired glass required and get a price on that basis for his estimate.

208. Sub-Contracts. The sub-contracts on buildings are usually very little trouble to the builder. He gets these proposals from the roofer, plumber, steam fitter, electrician, and painter and introduces them into his estimate. Sufficient knowledge of prevailing prices should be had by the builder, however, to make sure that he does not introduce a figure which is too low, causing any amount of trouble later. He should also be sure of his contractor, as he is responsible to the owner for all the work done on the building.

209. Overhead and Profit. The question of overhead and profit is one which rests with each individual builder. If he is small and does his business on an economical basis his overhead may not run over 5 per cent, but if he is a large contractor and he attempts a small job, he must not forget that he is organized for big work and thus requires a larger overhead. The profit on a job will vary with its size. On small jobs a profit of 20 per cent is not excessive because of the possibilities of its being wiped out by some error. If the work is large some contractors have been known to figure as low as an 8 per cent profit.

APPENDIX A

AGGREGATES

1. Origin and Requirements of Fine Aggregates. Sand, the name ordinarily given to fine aggregates, is formed by the physical disintegration of rocks. This may be a natural process or may be accomplished by the hand of man.

Diametrically opposed to this process is the decomposition of material to form clay and silt. This process is chemical in its nature and the resulting materials are of a different makeup. When a substance undergoes disintegration the resulting materials partake of the same physical characteristics as the substance from which they came. Their structure therefore should be similar to their base and their qualities likewise. Decomposition, however, destroys the qualities of the parent base and it is for this reason that sands containing clay and silt are considered detrimental to good concrete.

As most rocks contain silica, which is also known as quartz, the disintegration results in a mass of finely divided quartz particles. Should the rock contain any substances which are readily decomposed these parts will grind up into a fine substance and will be carried away by the wind and water. The fact that the quartz particles have survived this action is a good proof of their desirable qualities for concrete work.

Some sands may be formed from the disintegration of fossiliferous rock, which is formed in nature by the cementing together of many small shells of sea animals, of which coquina limestone is a fine example. Sands formed in this manner often contain complete shells which are still cellular in structure, and naturally enough, a concrete made with such fine aggregate will not be strong.

Screenings resulting from the crushing of rock, if devoid of clay and silt are good fine aggregates, after the dust is washed out. If the parent rock is limestone they should be re-rolled in order to avoid the flat pieces that limestone naturally breaks up into. The more nearly spherical the aggregate is the more impervious will be the concrete, as the particles are better able to bed closely together. Soft limestone screenings are a dangerous aggregate and should be avoided.

Density is of extreme importance in concrete that is to be exposed to water. A porous concrete will allow the water to percolate through it, thereby dissolving out the softer portions, leaving dangerous pockets in the mass.

Fine aggregates are found in pockets, beaches, or river beds. The first may be the result of glacial action or on the site of an old lake bed. The beaches and beds of lakes, oceans and rivers are nearly always lined with sand due to the erosion of the waves and water movement upon the coast or river drainage area. Those sands which are known to be of purely glacial origin are usually clean. The others are either filled with minute organic life or silt and are very often so fine that they are not usable without being mixed with larger aggregate.

The requirements imposed upon fine aggregate are that it should be clean, and well graded in size. The first characteristic cannot be given too much prominence. It has been proven time and time again that sands made up of round grains are usually as strong as those whose composition is of sharp grains. Coarse sands require less water in mixing and are to be preferred.

2. Origin and Requirements of Coarse Aggregates. It might have been stated in the discussion of fine aggregates, that coarse aggregates originated in a like manner in many respects. All that has been said regarding the relation of the aggregate to the parent rock holds true here.

The parent rocks that make a good concrete aggregate may be divided into three classes — igneous, sedimentary, and artificially formed.

The two main divisions of igneous rocks are granite and trap; the two main divisions of sedimentary rocks are sandstone and limestone; and the two kinds of rock, if one could call them by that name, which result from artificial processes are blast furnace slag and cinders.

Granite is made up of crystallized substances entirely. These are usually quartz, orthoclase, and mica horne-blendes. Being crystalline in structure, granite possesses the hardness required by concrete; at the same time this characteristic causes a low toughness. The constituent parts are possessed of varying coefficients of expansion under heat and thus readily disintegrate under this agent.

Trap rock which includes many of the "green stones," is of high abrasive value; it develops a good bond of cement. It has a fine, well bound, mineral structure and a fairly high crushing strength. It is apt to have a large proportion of low iron oxides in its composition, which is an undesirable feature, as the absorption of oxygen causes expansion. It is a very good aggregate.

Sandstone is one of the most important sedimentary rocks. It is based upon the igneous rocks which through the ages have been ground down, carried by water, either in solution or in suspension, and deposited with other material, such as iron or clay, into beds, where it has cemented together. Quartz forms by far the larger portion of its makeup but sometimes softer minerals such as feldspar are found in it. The strength of the stone is naturally based upon the material which cements the grains together. If this is iron oxide, which indicates its presence by the color of the stone, the better type of sandstone is formed. If it is clay the stone should not be used in concrete, as this material may dissolve out, leaving a sand pocket where a hard stone was intended.

Limestone is formed by the deposition of carbonate of lime upon the bottoms of bodies of water. This is accomplished by precipitation either from the water direct or by the agency of organic life. It varies greatly in hardness, from crystalline to soft texture. A good compact limestone varies in texture from very fine as in marbles, to very coarse. It occurs in white, gray, yellow, blue and green. If any great proportion of clay is present in it, it is very undesirable for concrete.

Blast furnace slag, as its name indicates, is the product of blast furnaces and is very often high in its percentage of sulphur. If this can be removed it makes a very strong concrete inasmuch as its pitted surface presents the possibility of a good cement bond. It forms a concrete light in weight and cheap.

Furnace cinders likewise are good enough for the aggregate of a mass concrete, but where reinforced concrete is necessary they should not be used. It is exceptionally high in its sulphur content and it has been known to eat conduit pipes and even structural shapes which were embedded in it.

3. Scientific Proportioning. The principle underlying dense concrete, which usually shows the greatest strength and durability, is that the gradation of the particles should be such that all voids will be filled and all surfaces of the aggregate covered with mortar. Sand of good quality therefore is rather coarse appearing, as the amount of fine material should be small. The stone should be well graded, too, the largest size being restricted to 1½ inches in order that the material may fit closely around the steel and surfaces of the forms. The larger the stones the denser the concrete and the smaller the surface area to be covered by cement. Hence cement is saved by adhering to these specifications in grading.

4 . **The Ideal Curve.** There is a point at which proportions of aggregates will be such that the maximum density will result with a given proportion of cement. This proportion of cement will vary with the mix and may be considered as given in Table XXXIX.

TABLE XXXIX

PROPORTIONS OF CEMENT FOR ARBITRARY MIXES

Mix	Cement	Aggregate (graded)
1-1-2	1	3.0
1-1½-3	1	4.5
1-2-4	1	6.0
1-2¼-5	1	7.5
1-3-6	1	9.0

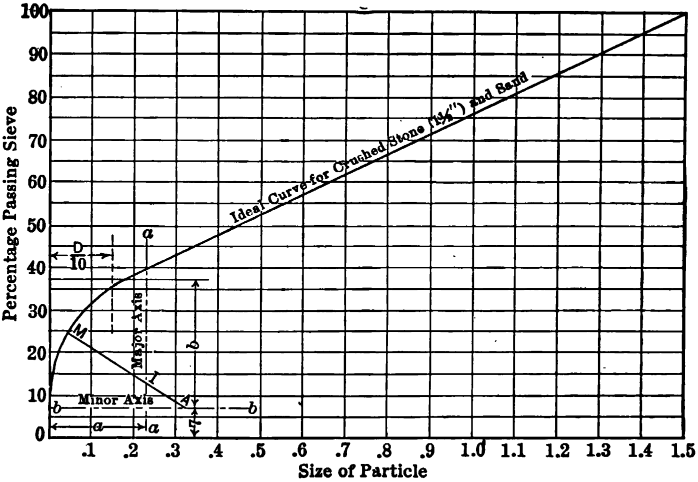

FIG. 197. IDEAL CURVE OF 1½-INCH STONE, AND SAND.

When the aggregates are mixed in a proportion to produce this maximum density they would present an ideal curve as shown in Fig. 197.

This curve is based upon rules determined by William B. Fuller and Sanford E. Thompson in their tests at Jerome Park Reservoir, N. Y., in 1903 and 1904.* These were very extensive and reasonably conclusive and the student is referred to the report for further study of them.

To plot this curve,† join the point where the diameter of the largest stone — 1½ in this case — reaches the 100 per cent line, with the point of the ordinate, giving zero diameter, equal to the value given in Column (1) of the following table:

TABLE XL

DATA FOR PLOTTING CURVES OF PRACTICAL MIX

Materials	Intersection of tangent with vertical at zero diameter (1)	Height of tangent point (2)	Axes of Ellipse (a) (3)	Axes of Ellipse (b + 7) (4)
Crushed stone and sand..	28.5	35.7	0.150 D	37.4
Gravel and sand.........	26.0	33.4	0.164 D	35.6
Crushed stone and screenings..................	29.0	36.1	0.147 D	37.8

In this table D equals the maximum diameter of the stone in inches. Then mark the tangent point on this line where the ordinate for $\frac{1}{10}$ the size of the maximum stone, 0.15, intersects it. This mark should check with the values given in column (2) of Table XL. Next plot the axes of the ellipse from the value of (a) and (b + 7) given in columns (3) and (4) respectively of the table. Note that the major axis is placed on the 7 per cent line. The ellipse may then be plotted by laying off the length of the two axes upon a strip of paper to the scale of the curve, as shown in Fig. 198.

The points I and A of this strip are kept upon the axes "A" and "B" of the plot while the strip is revolved so that the point M starts at the tangent point and moves to the line of zero percentage.

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* Transactions A.S.C.E., Vol. 59, 1907.

† Chapter X, Taylor and Thompson's "Reinforced Concrete," 3rd edition. Copyrighted 1915–16 by Taylor and Thompson, "Combining Sand and Stone Curves."

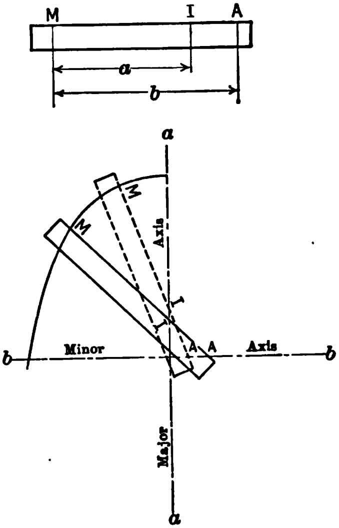

FIG. 198. LAYING OUT AN ELLIPSE.

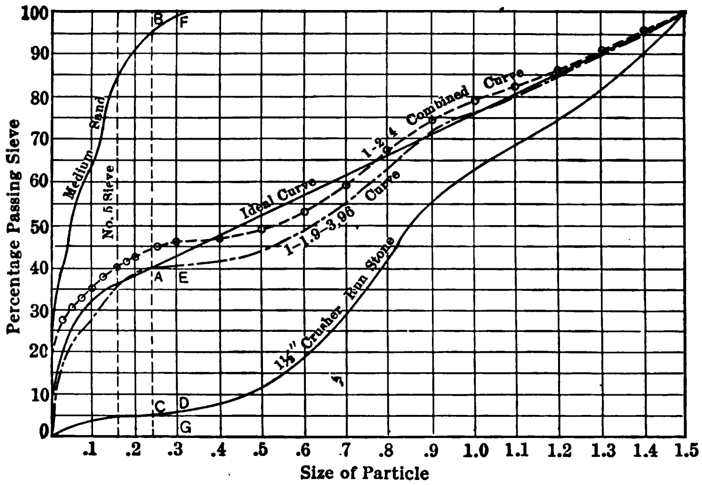

FIG. 199. GRADING CURVES FOR SAND AND STONE SHOWING THE RELATION OF THE IDEAL CURVE TO THE COMBINED CURVE.

Fig. 199 shows the sieve analysis of a sand and stone delivered upon this job while the specifications call for an arbitrary mix of 1–2–4. By a reference to Table XXXIX it is found that the cement is $\frac{1}{7}$ of the total volume, the sand $\frac{2}{7}$, and the stone $\frac{4}{7}$. To find the point where the combined curve intersects the ordinate corresponding to a No. 5 sieve, the sum of the percentages of each material at this ordinate is taken in the proportion they bear to the entire concrete mixture. As the cement is finer than the No. 5 sieve, it would all pass the sieve. Therefore $\frac{1}{7}$ of 100 per cent would represent the amount of cement at this point in the mix, or 14.3 per cent. As the percentage of the sand passing this sieve would be 85 and $\frac{2}{7}$ of the mixture is sand, $\frac{2}{7} \times 85$ per cent or 24.3 per cent is the amount of sand at this point in the mix. Likewise the percentage of stone in the mix at this point would be $\frac{4}{7} \times 4$ per cent or 2.3 per cent. The ordinate of the combined curve at this point would then be $14.3 + 24.3 + 2.3 = 40.9$ per cent. In this way enough points may be plotted to form the entire curve as shown in Fig. 199.

It has been found by density tests of mixed aggregates that the best results have been obtained when the combined curve intersected the ideal curve at this point, about the 40 per cent line. This gives us the point *A* on the ideal curve. The proportion of sand and cement is $\frac{CA}{CB} = 38.1$ per cent, while $\frac{BA}{BC} = 61.9$ per cent is the proportion of stone.

To get the combined curve which will intersect the ideal curve at the 40 per cent ordinate, each point, for example, can be determined as follows:

$$GD\,(61.9) + GF\,(38.1) = GE = 41.8.$$

If this curve follows the ideal curve very nearly, we can find the proportions of the mix. As the cement is $\frac{1}{7}$ of the entire mix by weight, it will be 14.3; the amount of sand will be $38.1 - 14.3 = 23.8$ per cent, and the stone is 61.9 per cent. This gives the mix by weight of 1–1.66–4.33. To find the proportions of the mix by volume, which is the way in which they must be proportioned on the job, it will be necessary to calculate it as follows:

	Pounds
1 bag of cement weighs........................	94
1.66 × weight of cement in sand	156
4.33 × weight of cement in stone................	407
1 cubic foot cement weighs......................	94

Use 1 part by volume of cement.

1 cubic foot sand weighs........................ 82

Use 156/82 of 1.9 parts volume of sand.

1 cubic foot stone weighs........................ 103

Use 407/103 or 3.96 parts volume of stone.

The practical mix corresponding to the arbitrary 1 : 2 : 4 mix is, therefore, 1–1.9–3.96.

In this way an analysis can be made of the materials arriving on the job from time to time and the mix can be varied to meet the conditions of maximum density.

APPENDIX B

MANUFACTURE OF CEMENT

The two cementing materials which are being used mostly in modern concrete work are, as mentioned in Chapter III, natural and Portland cement.

Natural cement is made from a natural clayey limestone, which is burned, at a temperature varying from about 1650° to 2370° F. It is readily seen that the quantity of this cement which can be manufactured is dependent upon the extent of the natural rock deposits. Its quality will depend upon the composition of the deposit.

Portland cement, on the contrary, is an artificial product definitely proportioned, containing clay and lime substances (argillaceous and calcareous). Five combinations have been used in different sections of the country, namely:

1. Cement rock and limestone.
2. Marl and clay.
3. Limestone and clay.
4. Blast-furnace slag and limestone.
5. Chalk and clay.

The steps in the manufacture of Portland cement are: Mixing and grinding the materials, burning to a clinker, cooling, and grinding the clinker. Two processes are used, the wet and the dry. By far the larger proportion of the Portland cement plants in the United States utilize the dry process. The burning is done in rotary cylindrical kilns. These are immense steel cylinders slightly inclined with the horizontal, so that the materials are carried forward by the revolution of the kiln. The materials are fed in at the high end while the hot gases are fed in from the lower end. The process causes the formation of clinkers varying from $\frac{1}{4}$ to $1\frac{1}{4}$ inches in size. The clinker is then cooled, crushed and ground preliminarily. About 2 per cent of gypsum (or plaster of Paris) is added and the mixture ground to a fine powder (impalpable). (See Fig. 200.)

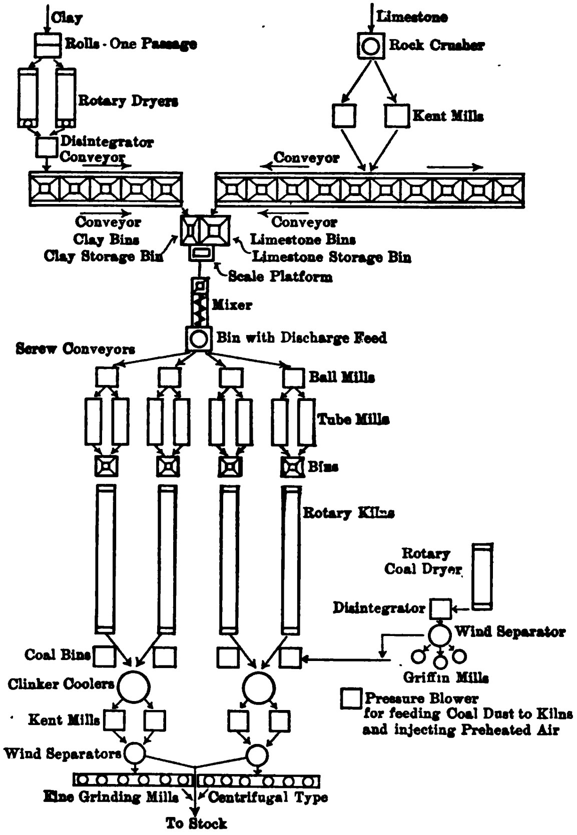

FIG. 200. THE MANUFACTURE OF PORTLAND CEMENT.

APPENDIX C

STANDARD SPECIFICATIONS AND TESTS FOR PORTLAND CEMENT

Authorized Reprint from the Copyrighted A.S.T.M. Standards (1916)
American Society for Testing Materials, Philadelphia, Pa.

Serial Designation: C 9–17

1. Definition. Portland cement is the product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination excepting water and calcined or uncalcined gypsum.

I. Chemical Properties

2. Chemical Limits. The following limits shall not be exceeded:

Loss on ignition, per cent	4.00
Insoluble residue, per cent	0.85
Sulfuric anhydride (SO_3), per cent	2.00
Magnesia (MgO), per cent	5.00

II. Physical Properties

3. Specific Gravity. The specific gravity of cement shall be not less than 3.10 (3.07 for white Portland cement). Should the test of cement as received fall below this requirement a second test may be made upon an ignited sample. The specific gravity test will not be made unless specifically ordered.

4. Fineness. The residue on a standard No. 200 sieve shall not exceed 22 per cent by weight.

5. Soundness. A pat of neat cement shall remain firm and hard, and show no signs of distortion, cracking, checking, or disintegration in the steam test for soundness.

6. Time of Setting. The cement shall not develop initial set in less than 45 minutes when the Vicat needle is used or 60 minutes when the Gillmore needle is used. Final set shall be attained within 10 hours.

7. Tensile Strength. The average tensile strength in pounds per square inch of not less than three standard mortar briquettes (see Section 51) composed of one part cement and three parts standard sand, by weight, shall be equal to or higher than the following:

Age at test, days	Storage of briquette	Tensile strength, lbs. per sq. in.
7	1 day in moist air, 6 days in water......	200
28	1 day in moist air, 27 days in water.....	300

8. The average tensile strength of standard mortar at 28 days shall be higher than the strength at 7 days.

III. PACKAGES, MARKING AND STORAGE

9. Packages and Marking. The cement shall be delivered in suitable bags or barrels with the brand and name of the manufacturer plainly marked thereon, unless shipped in bulk. A bag shall contain 94 pounds net. A barrel shall contain 376 pounds net.

10. Storage. The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a suitable weather-tight building which will protect the cement from dampness.

IV. INSPECTION

11. Inspection. Every facility shall be provided the purchaser for careful sampling and inspection at either the mill or at the site of the work, as may be specified by the purchaser. At least 10 days from the time of sampling shall be allowed for the completion of the 7-day test, and at least 31 days shall be allowed for the completion of the 28-day test. The cement shall be tested in accordance with the methods hereinafter prescribed. The 28-day test shall be waived only when specifically so ordered.

V. REJECTION

12. Rejection. The cement may be rejected if it fails to meet any of the requirements of these specifications.

13. Cement shall not be rejected on account of failure to meet the fineness requirement if upon retest after drying at 100° C. for one hour it meets this requirement.

14. Cement failing to meet the test for soundness in steam may be accepted if it passes a retest using a new sample at any time within 28 days thereafter.

15. Packages varying more than 5 per cent from the specified weight may be rejected; and if the average weight of packages in any shipment, as shown by weighing 50 packages taken at random, is less than that specified, the entire shipment may be rejected.

TESTS

VI. SAMPLING

16. Number of Samples. Tests may be made on individual or composite samples as may be ordered. Each test sample should weigh at least 8 pounds.

17. (*a*) **Individual Sample.** If sampled in cars one test sample shall be taken from each 50 barrels or fraction thereof. If sampled in bins one sample shall be taken from each 100 barrels.

(*b*) **Composite Sample.** If sampled in cars one sample shall be taken from one sack in each 40 sacks (or 1 barrel in each 10 barrels) and combined to form one test sample. If sampled in bins or warehouses one test sample shall represent not more than 200 barrels.

18. Method of Sampling. Cement may be sampled at the mill by any of the following methods that may be practicable, as ordered:

(*a*) **From the Conveyor Delivering to the Bin.** At least 8 pounds of cement shall be taken from approximately each 100 barrels passing over the conveyor.

(*b*) **From Filled Bins by Means of Proper Sampling Tubes.** Tubes inserted vertically may be used for sampling cement to a maximum depth of 10 feet. Tubes inserted horizontally may be used where the construction of the bin permits. Samples shall be taken from points well distributed over the face of the bin.

(*c*) **From Filled Bins at Points of Discharge.** Sufficient cement shall be drawn from the discharge openings to obtain samples representative of the cement contained in the bin, as determined by the appearance at the discharge openings of indicators placed on the surface of the cement directly above these openings before drawing of the cement is started.

19. Treatment of Sample. Samples preferably shall be shipped and stored in air-tight containers. Samples shall be passed through a sieve having 20 meshes per linear inch in order to thoroughly mix the sample, break up lumps and remove foreign materials.

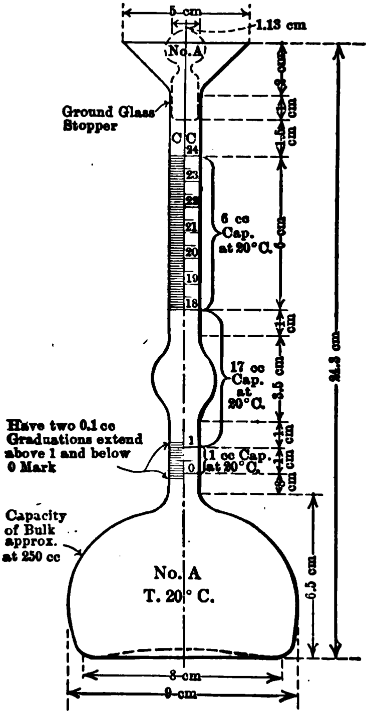

FIG. 201. LE CHATELIER APPARATUS.

VII. CHEMICAL ANALYSIS (omitted)

VIII. DETERMINATION OF SPECIFIC GRAVITY

28. Apparatus. The determination of specific gravity shall be made with a standardized Le Chatelier apparatus which conforms to the requirements illustrated in Fig. 201. This apparatus is standardized by the United States Bureau of Standards. Kerosene free from water, or benzine not lighter than 62° Baumé, shall be used in making this determination.

29. Method. The flask shall be filled with either of these liquids to a point on the stem between zero and one cubic centimeter, and 64 grams of cement, of the same temperature as the liquid, shall be slowly introduced, taking care that the cement does not adhere to the inside of the flask above the liquid and to free the cement from air by rolling the flask in an inclined position. After all the cement is introduced, the level of the liquid will rise to some division of the graduated neck; the difference between readings is the volume displaced by 64 grams of the cement.

The specific gravity shall then be obtained from the formula

$$\text{Specific gravity} = \frac{\text{Weight of cement (g.)}}{\text{Displaced volume (c.c.)}}.$$

30. The flask, during the operation, shall be kept immersed in water, in order to avoid variations in the temperature of the liquid in the flask, which shall not exceed 0.5° C. The results of repeated tests should agree within 0.01.

31. The determination of specific gravity shall be made on the cement as received; if it falls below 3.10, a second determination shall be made after igniting the sample as described in Section 20.

IX. DETERMINATION OF FINENESS

32. Apparatus. Wire cloth for standard sieves for cement shall be woven (not twilled) from brass, bronze, or other suitable wire, and mounted without distortion on frames not less than 1½ inches below the top of the frame. The sieve frames shall be circular, approximately 8 inches in diameter, and may be provided with a pan and cover.

33. A standard No. 200 sieve is one having nominally an 0.0029-inch opening and 200 wires per inch standardized by the U. S. Bureau of Standards, and conforming to the following requirements:

The No. 200 sieve should have 200 wires per inch, and the number of wires in any whole inch shall not be outside the limits of 192 to 208. No opening between adjacent parallel wires shall be more than 0.0050 inch in width. The diameter of the wire should be 0.0021 inch and the average diameter shall not be outside the limits 0.0019 to 0.0023 inch. The value of the sieve as determined by sieving tests made in conformity with the standard specification for these tests on a standardized cement which gives a residue of 25 to 20 per cent on the No. 200 sieve, or on other similarly graded material, shall not show a variation of more than 1.5 per cent above or below the standards maintained at the Bureau of Standards.

34. Method. The test shall be made with 50 grams of cement. The sieve shall be thoroughly clean and dry. The cement shall be placed on the No. 200 sieve, with pan and cover attached, if desired, and shall be held in one hand in a slightly inclined position so that the sample will be well distributed over the sieve, at the same time gently striking the side about 150 times per minute against the palm of the other hand on the up stroke. The sieve shall be turned every 20 strokes about one-sixth of a revolution in the same direction. The operation shall continue until not more than 0.05 g. passes through in one minute of continuous sieving. The fineness shall be determined from the weight of the residue on the sieve expressed as a percentage of the weight of the original sample.

35. Mechanical sieving devices may be used, but the cement shall not be rejected if it meets the fineness requirement when tested by the hand method described in Section 34.

36. Permissible Variation. A permissible variation of 1 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 22 per cent.

X. Mixing Cement Pastes and Mortars

37. Method. The quantity of dry material to be mixed at one time shall not exceed 1000 grams nor be less than 500 grams. The proportions of cement or cement and sand shall be stated by weight in grams of the dry materials; the quantity of water shall be expressed in cubic centimeters (1 c.c. of water = 1 gram). The dry materials shall be weighed, placed upon a non-absorbent surface, thoroughly mixed dry if sand is used, and a crater formed in the center, into which the proper percentage of clean water shall be poured; the material on the outer edge shall be turned into the crater by the aid of a trowel. After an interval of one-half minute for the absorption of the water the operation shall be completed by continuous, vigorous mixing, squeezing and kneading with the hands for at least one minute.* During the operation of mixing, the hands should be protected by rubber gloves.

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* In order to secure uniformity in the results of tests for the time of setting and tensile strength the manner of mixing above described should be carefully followed. At least one minute is necessary to

38. The temperature of the room and the mixing water shall be maintained as nearly as practicable at 21° C. (70° F.).

XI. NORMAL CONSISTENCY

39. Apparatus. The Vicat apparatus consists of a frame *A* (Fig. 202) bearing a movable rod *B*, weighing 300 grams, one end *C* being 1 cm. in diameter for a distance of 6 cm., the other having a removable needle *D*, 1 mm. in diameter, 6 cm. long. The rod is reversible, and can be held in any desired position by a screw *E*, and has midway between the ends a mark *F* which moves under a scale (graduated to millimeters) attached to the frame *A*. The paste is held in a conical, hard-rubber ring *G*, 7 cm. in diameter at the base, 4 cm. high, resting on a glass plate *H* about 10 cm. square.

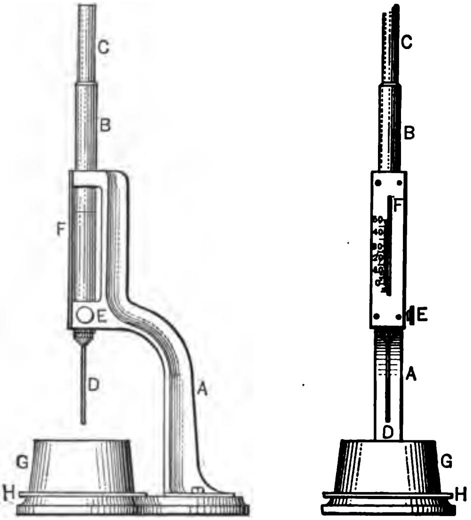


FIG. 202. THE VICAT APPARATUS.

40. Method. In making the determination, 500 grams of cement, with a measured quantity of water, shall be kneaded into

obtain the desired plasticity which is not appreciably affected by continuing the mixing for several minutes. The exact time necessary is dependent upon the personal equation of the operator. The error in mixing should be on the side of over-mixing.

a paste, as described in Section 37, and quickly formed into a ball with the hands, completing the operation by tossing it six times from one hand to the other, maintained about 6 inches apart; the ball resting in the palm of one hand shall be pressed into the larger end of the rubber ring held in the other hand, completely filling the ring with paste; the excess at the larger end shall then be removed by a single movement of the palm of the hand; the ring shall then be placed on its larger end on a glass plate and the excess paste at the smaller end sliced off at the top of the ring by a single oblique stroke of a trowel held at a slight angle with the top of the ring. During these operations care shall be taken not to compress the paste. The paste confined in the ring, resting on the plate, shall be placed under the rod, the larger end of which shall be brought in contact with the surface of the paste; the scale shall be then read, and the rod quickly released. The paste shall be of normal consistency when the rod settles to a point 10 mm. below the original surface in one-half minute after being released. The apparatus shall be free from all vibrations during the test. Trial pastes shall be made with varying percentages of water until the normal consistency is obtained. The amount of water required shall be expressed in percentage by weight of the dry cement.

TABLE XLI

PERCENTAGE OF WATER FOR STANDARD MORTARS

Percentage of water for neat cement paste of normal consistency	Percentage of water for one cement, three standard Ottawa sand	Percentage of water for neat cement paste of normal consistency	Percentage of water for one cement, three standard Ottawa sand
15	9.0	23	10.3
16	9.2	24	10.5
17	9.3	25	10.7
18	9.5	26	10.8
19	9.7	27	11.0
20	9.8	28	11.2
21	10.0	29	11.3
22	10.2	30	11.5

41. The consistency of standard mortar shall depend on the amount of water required to produce a paste of normal consistency from the same sample of cement. Having determined the normal consistency of the sample, the consistency of standard mortar made from the same sample shall be as indicated in Table XLI, the values being in percentage of the combined dry weights of the cement and standard sand.

XII. DETERMINATION OF SOUNDNESS *

42. Apparatus. A steam apparatus, which can be maintained at a temperature between 98° and 100° C., or one similar to that shown in Fig. 203, is recommended. The capacity of this apparatus may be increased by using a rack for holding the pats in a vertical or inclined position.

43. Method. A pat from cement paste of normal consistency about 3 inches in diameter, ½ inch thick at the center, and tapering to a thin edge, shall be made on clean glass plates about 4 inches square, and stored in moist air for 24 hours. In moulding the pat, the cement paste shall first be flattened on the glass and the pat then formed by drawing the trowel from the outer edge toward the center.

44. The pat shall then be placed in an atmosphere of steam at a temperature between 98° and 100° C. upon a suitable support 1 inch above boiling water for 5 hours.

45. Should the pat leave the plate, distortion may be detected best with a straight edge applied to the surface which was in contact with the plate.

XIII. DETERMINATION OF TIME OF SETTING

46. The following are alternate methods, either of which may be used as ordered:

47. Vicat Apparatus. The time of setting shall be determined with the Vicat apparatus described in Section 39. (See Fig. 202.)

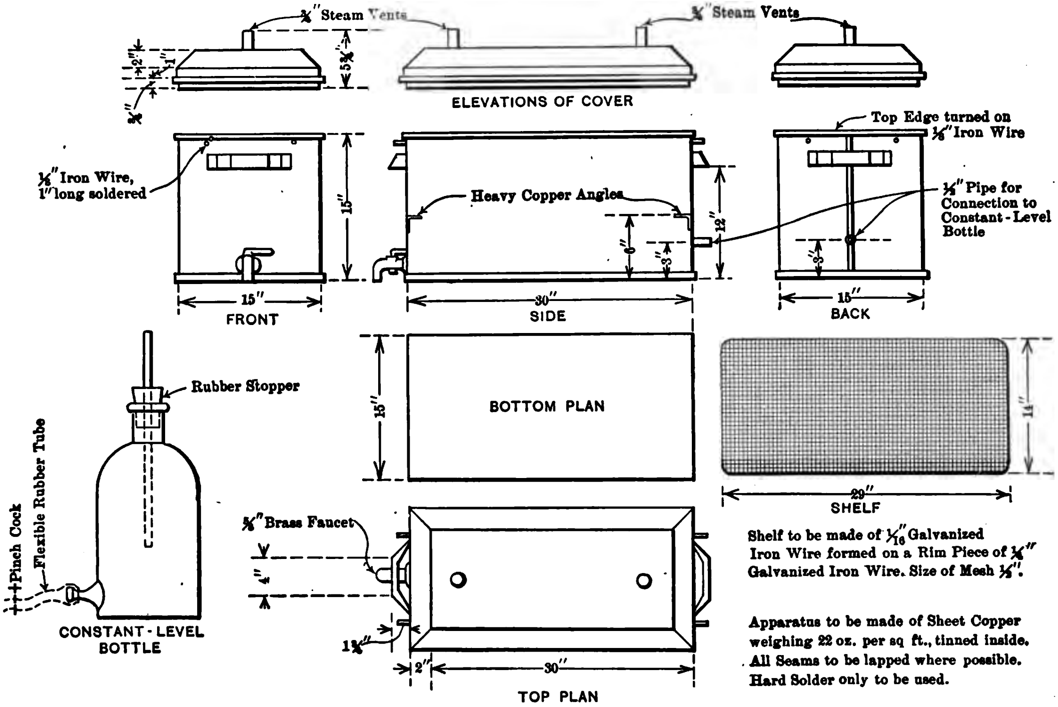
48. Vicat Method. A paste of normal consistency shall be moulded in the hard-rubber ring *G* as described in Section 40, and placed under the rod *B*, the smaller end of which shall then be carefully brought in contact with the surface of the paste, and the

---

* Unsoundness is usually manifested by change in volume which causes distortion, cracking, checking or disintegration.

Pats improperly made or exposed to drying may develop what are known as shrinkage cracks within the first 24 hours and are not an indication of unsoundness. These conditions are illustrated in Fig. 4 of the original report.

The failure of the pats to remain on the glass or the cracking of the glass to which the pats are attached does not necessarily indicate unsoundness.



Shelf to be made of 1/16" Galvanized Iron Wire formed on a Rim Piece of ¼" Galvanized Iron Wire. Size of Mesh ½".

Apparatus to be made of Sheet Copper weighing 22 oz. per sq ft., tinned inside. All Seams to be lapped where possible. Hard Solder only to be used.

FIG. 203. APPARATUS FOR MAKING THE SOUNDNESS TEST OF CEMENT.

rod quickly released. The initial set shall be said to have occurred when the needle ceases to pass a point 5 mm. above the glass plate in one-half minute after being released; and the final set, when the needle does not sink visibly into the paste. The test pieces shall be kept in moist air during the test. This may be accomplished by placing them on a rack over water contained in a pan and covered by a damp cloth, kept from contact with them by means of a wire screen; or they may be stored in a moist closet. Care shall be taken to keep the needle clean, as the collection of cement on the sides of the needle retards the penetration, while cement on the point may increase the penetration. The time of setting is affected not only by the percentage and temperature of the water used and the amount of kneading the paste receives, but by the temperature and humidity of the air, and its determination is therefore only approximate.

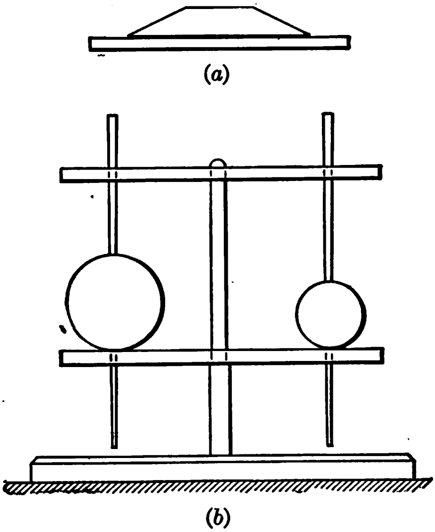


Fig. 204. The Gillmore Needles.
(*a*) Pat mounted upon glass.
(*b*) Rack for mounting Gillmore needles.

49. Gillmore Needles. The time of setting shall be determined by the Gillmore needles. The Gillmore needles should preferably be mounted as shown in Fig. 204b.

50. Gillmore Method. The time of setting shall be determined as follows: A pat of neat cement paste about 3 inches in diameter and ½ inch in thickness with a flat top (Fig. 204a), mixed to a normal consistency, shall be kept in moist air at a temperature maintained as nearly as practicable at 21° C. (70° F.). The cement shall be considered to have acquired its initial set when the pat will bear, without appreciable indentation, the Gillmore needle $\frac{1}{12}$ inch in diameter, loaded to weigh ¼ pound. The final set has been acquired when the pat will bear without appreciable indentation, the Gillmore needle $\frac{1}{24}$ inch in diameter, loaded to weigh 1 pound. In making the test, the needles shall be held in a vertical position, and applied lightly to the surface of the pat.

XIV. Tension Tests

51. Form of Test Piece. The form of test piece shown in Fig. 205 shall be used. The moulds shall be made of non-corroding metal and have sufficient material in the sides to prevent spreading during moulding. Gang moulds when used shall be of the type shown in Fig. 206. Moulds shall be wiped with an oily cloth before using.

52. Standard Sand. The sand to be used shall be natural sand from Ottawa, Ill., screened to pass a No. 20 sieve and retained on a No. 30 sieve. This sand may be obtained from the Ottawa Silica Company, at a cost of two cents per pound, f.o.b. cars, Ottawa, Ill.

53. This sand, having passed the No. 20 sieve, shall be considered standard when not more than 5 grams pass the No. 30 sieve after one minute continuous sieving of a 500-gram sample.

54. The sieve shall conform to the following specifications:

The No. 20 sieve shall have between 19.5 and 20.5 wires per whole inch of the warp wires and between 19 and 21 wires per whole inch of the shoot wires. The diameter of the wire should be 0.0165 inch and the average diameter shall not be outside the limits of 0.0160 and 0.0170 inch.

The No. 30 sieve shall have between 29.5 and 30.5 wires per whole inch of the warp wires and between 28.5 and 31.5 wires per whole inch of the shoot wires. The diameter of the wire should be 0.0110 inch and the average diameter shall not be outside the limits 0.0105 to 0.0115 inch.

55. Moulding. Immediately after mixing, the standard mortar shall be placed in the moulds, pressed in firmly with the thumbs and smoothed off with a trowel without ramming. Additional mortar shall be heaped above the mould and smoothed off with a trowel; the trowel shall be drawn over the mould in such a manner as to exert a moderate pressure on the material. The mould shall then be turned over and the operation of heaping, thumbing and smoothing off repeated.

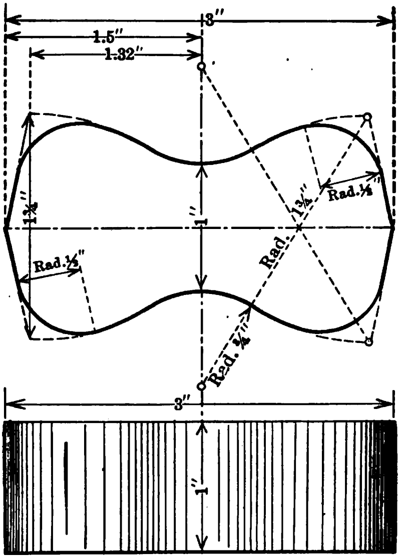


FIG. 205. STANDARD BRIQUETTE.

56. Testing. Tests shall be made with any standard machine. The briquettes shall be tested as soon as they are removed from the water. The bearing surfaces of the clips and briquettes shall be free from grains of sand or dirt. The briquettes shall be carefully centered and the load applied continuously at the rate of 600 pounds per minute.

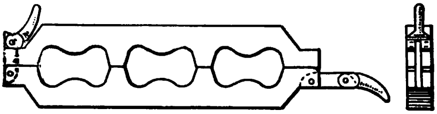


FIG. 206. BRIQUETTE MOULD.

57. Testing machines should be frequently calibrated in order to determine their accuracy.

58. Faulty Briquettes. Briquettes that are manifestly faulty, or which give strengths differing more than 15 per cent from the average value of all test pieces made from the same sample and broken at the same period, shall not be considered in determining the tensile strength.

XV. STORAGE OF TEST PIECES

59. Apparatus. The moist closet may consist of a soapstone, slate or concrete box, or a wooden box lined with metal. If a wooden box is used, the interior should be covered with felt or broad wicking kept wet. The bottom of the moist closet should be covered with water. The interior of the closet should be provided with non-absorbent shelves on which to place the test pieces, the shelves being so arranged that they may be withdrawn readily.

60. Methods. Unless otherwise specified all test pieces, immediately after moulding, shall be placed in the moist closet for from 20 to 24 hours.

61. The briquettes shall be kept in moulds on glass plates in the moist closet for at least 20 hours. After 24 hours in moist air the briquettes shall be immersed in clean water in storage tanks of non-corroding material.

62. The air and water shall be maintained as nearly as practicable at a temperature of 21° C. (70° F.).

APPENDIX D

SUGGESTED SPECIFICATIONS FOR CONCRETE STORAGE TANKS OR RESERVOIRS

November, 1917. Authorized Report A.C.I.

These specifications apply to tanks of moderate capacity and cover the preparation of the site, construction of the tank, and the protection of the concrete while hardening.

GRADING

Excavation. Excavation shall be made to the proper depth and size, allowing for exterior forms where required. All roots, sod and any other refuse material shall be removed, and all soft or spongy spots shall be excavated and the holes refilled with well-tamped sand or gravel.

For tanks built at ground level proper excavation shall be made for footings.

Back Filling. All back filling is deposited in well tamped six (6) inch layers. Back filling for the walls shall not be placed within four (4) weeks after the forms have been removed. Should any part of the graded floor area be slightly below the proper elevation, the depressions thus resulting shall be filled with concrete rather than with sand or gravel.

Drainage and Plumbing. Proper provision shall be made for drainage around the outer and lower edge of the wall footings and under the floor of the tank when necessary. The necessary plumbing for filling and emptying the tank shall be provided and placed as required.

MATERIALS

Cement. The cement shall meet the requirements of the current Standard Specifications and Tests for Portland Cement of the American Society for Testing Materials.

Aggregates. Before delivery on the job, the contractor shall submit to the engineer a fifty (50) pound sample of each of the aggregates proposed for use. These samples shall be tested and if found to pass the requirement of the specifications, similar material shall be considered as acceptable for the work. In no case shall aggregates containing frost or lumps of frozen material be used.

Fine Aggregate. Fine aggregate shall consist of natural sand or screenings from hard, tough, crushed rock or gravel consisting of quartz grains or other equally hard material, graded from fine to coarse, with the coarse particles predominating. Fine aggregate, when dry, shall pass a screen having four (4) meshes to the linear inch; not more than twenty-five (25) per cent shall pass a sieve having fifty (50) meshes per linear inch, and not more than five (5) per cent shall pass a sieve having one hundred (100) meshes per linear inch. Fine aggregate shall not contain vegetable or other organic matter nor more than three (3) per cent, by weight, of clay or loam. Field tests may be made by the engineer on fine aggregate as delivered at any time during progress of the work. If there is more than seven (7) per cent of clay or loam, by volume, in one (1) hour's settlement after shaking in a 100 per cent excess of water, the material represented by the sample shall not be used in the work.

Fine aggregates shall be of such quality that mortar composed of one (1) part Portland cement and three (3) parts fine aggregate, by weight, when made into briquettes or cylinders, shall show a tensile or compressive strength, at seven (7) and twenty-eight (28) days, at least equal to the strength of briquettes or cylinders composed of one (1) part of the same cement and three (3) parts Standard Ottawa sand, by weight. The percentage of water used in making the test specimens of cement and fine aggregate shall be such as to produce a mortar of the same consistency as that of the Ottawa sand test; specimens of standard consistency. In other respects all briquettes or cylinders shall be made in accordance with the methods of testing cement recommended by the American Society for Testing Materials. (See Cement Specifications A. S. T. M.)

Coarse Aggregate. Coarse aggregate shall consist of clean, hard, tough, crushed rock or pebbles graded in size, free from vegetable or other organic matter, and shall contain no soft, flat or elongated particles. The size of the coarse aggregate shall range from one (1) inch down, not more than five (5) per cent passing a screen having four (4) meshes per linear inch, and no intermediate sizes shall be removed.

Mixed Aggregate. Crusher-run stone, bank-run gravel or mixtures of fine and coarse aggregate prepared before delivery on the work shall not be used.

Water. Water shall be clean, free from oil, acid, alkali, or vegetable matter.

Reinforcement. The reinforcing metal shall meet the requirements of the current standard Specifications for Steel Reinforcement of the American Society for Testing Materials. It shall be free from excessive rust, scale, paint or coatings, of any character which will tend to reduce or destroy the bond. Either plain or deformed steel bars shall be used unless otherwise specified. When deformed bars are used they shall have a net cross-sectional area equivalent to that of the plain bars shown on the plans.

CONSTRUCTION

Forms. Forms shall be substantial, unyielding, and so constructed that the concrete will conform to the designed dimensions and contours, and shall also be tight to prevent the leakage of mortar. The forms for exposed surfaces shall be sound lumber planed to a uniform thickness, either tongued and grooved, or with edges beveled to make tight joints after erection. The forms for walls and the roof centering shall remain in place until time for removal, as hereinafter specified. All wood forms shall be thoroughly wetted and metal forms oiled or coated with soft soap or whitewash before depositing any material against them. All mortar and dirt shall be removed from forms that have been previously used.

Reinforcing. The necessary reinforcing metal shall be placed and held tightly in the exact location shown on the plans, so that it will not become disarranged during the depositing of the concrete. Whenever it is necessary to splice the reinforcement, the character of the splice shall be such as will develop the full strength of the metal. If the bars are to be lapped, not less than forty (40) times the diameter of the bar in inches should be allowed for the lap. The splices should not be vertically above one another, but should be spaced around the tank, each splice being a few feet past the one below.

MEASURING AND MIXING

Measuring. The method of measuring the materials for the concrete, including water, shall be one which will insure separate and uniform proportions of each of the materials at all times. A sack of Portland cement (94 pounds net) shall be considered one (1) cubic foot.

Machine Mixing. All concrete shall be mixed by machine except when the engineer shall otherwise permit under special conditions. A batch mixer of any approved type shall be used. The ingredients of the concrete or mortar shall be mixed to the specified consistency, and the mixing shall continue for at least one and one-half (1½) minutes after all materials are in the drum. The drum shall be completely emptied before receiving material for the succeeding batch.

Hand Mixing. When it is necessary to mix by hand, the materials shall be mixed dry on a watertight platform until the mixture is of a uniform color, the required amount of water added, and the mixing continued until the mass is homogeneous and of uniform consistency.

Retempering. Retempering of mortar or concrete which has partially hardened, that is, remixing with or without additional materials or water, shall not be permitted.

WALLS

Proportions. The concrete shall be mixed in the proportions of one (1) sack of Portland cement to not more than two (2) cubic feet of fine aggregate and not more than three (3) cubic feet of coarse aggregate; in no case shall the volume of the fine aggregate be less than one-half (½) the volume of the coarse aggregate.

A cubic yard of concrete in place shall contain not less than seven (7) cubic feet of cement.

Consistency. The materials shall be mixed wet enough to produce a concrete of such consistency that it may be worked into the forms and about the reinforcement but can be handled to place without a separation of the coarse aggregate from the mortar.

Placing. The concrete shall be placed in a manner that will permit the most thorough compacting and shall be worked into all recesses of the forms. Concrete shall be deposited in its full position as soon as possible after mixing and within thirty (30) minutes after the water has been added to the dry materials. Concrete for the walls shall be placed in as continuous an operation as possible so as to avoid construction joints.

Where the work is interrupted so that the last layer of the concrete shall have hardened before the next can be placed, the upper surface shall be left level, roughened and cleaned and shall then be covered with wet canvas until the work is resumed, at which time the surface shall be cleaned of all foreign material and laitance, drenched and slushed with a mortar mixed in the proportions of one (1) sack of Portland cement to two (2) cubic feet of fine aggregate. In addition, if required by the engineer, a strip of sheet metal not less than eight (8) inches wide shall be embedded longitudinally for half its width in the middle of the wall at each horizontal joint, so that the remaining portion will be embedded in the new concrete when work is resumed. Before placing, one inch of the strip along each edge shall be bent at right angles to the body of the strip for anchorage.

The concrete shall be placed in continuous horizontal layers and vertical joints avoided.

Floor and Roof.

Proportions. Concrete shall be mixed in the proportion of one (1) sack of Portland cement, two (2) cubic feet of fine aggregate and three (3) cubic feet of coarse aggregate.

Consistency. The materials shall be mixed wet enough to produce concrete of such consistency that it can be worked into the forms and about the reinforcement, but the consistency shall not be such as to cause a separation of the coarse aggregate from the mortar.

Placing. The concrete shall be placed in a manner to insure a smooth surface and be thoroughly worked around the metal reinforcement. It shall be deposited to the full thickness of the slab, and shall be brought to the established elevation with a strikeboard. Workmen shall not be permitted to walk on the freshly laid concrete.

Finishing. After the concrete has been brought to the established elevation by means of a strikeboard, it shall be floated with a wood float in a manner which will thoroughly compact it and provide a smooth, even surface. Finishers shall work from knee boards. When required, the surface shall be steel troweled, but excessive working shall be avoided.

General

Removal of Forms. The roof centering shall remain in place at least fourteen (14) days. The wall forms shall remain in place at least twenty-four (24) hours or until the concrete has hardened sufficiently to be self-sustaining or to sustain the weight of the forms and the next section of concrete above. When freezing weather occurs, forms and centering shall remain in place an additional time equal to the time the structure has been exposed to freezing. No outside pressure shall be placed on the concrete before the removal of the forms. The reservoir shall not be put into service within one (1) month after the forms have been removed.

Surface Finishes. Immediately after the forms have been removed all projections and irregularities on the exposed surfaces shall be carefully removed and all cavities neatly filled with mortar. Enough 1 : 2 cement and sand mortar shall be used to fill the cavities, but no plastering will be permitted. All exposed surfaces shall be finished to have a smooth and neat appearance, and where specified shall be scrubbed, tooled, or otherwise finished in an approved manner as directed by the engineer.

Treatment. The freshly finished concrete shall be protected from hot sun and drying winds. As soon as the floor has hardened sufficiently to prevent damage it shall be covered with at least one (1) inch of wet sand, or two (2) inches of sawdust which shall be kept wet by sprinkling with water for at least ten (10) days.

Temperature Below 35° F. If at any time during the progress of the work the temperature is, or in the opinion of the engineer will within twenty-four (24) hours drop to 35° F., the water and the aggregates shall be heated and precautions taken to protect the work from freezing for at least five (5) days.

APPENDIX E

TYPICAL WATERPROOF CONSTRUCTIONS

The points applying to concrete reservoirs apply largely to all structures which must sustain water action in various forms. It is with this purpose in view that Figs. 207, 208, 209, 210, 211, and 212 are given, also serving as a basis for further study of concrete details and estimates.

APPENDIX F

AUTHORIZED REPRINT OF ESTIMATING CONCRETE BUILDINGS

By Clayton W. Mayers. (Preface omitted.) Published and copyrighted by Aberthaw Construction Company,
Boston, Massachusetts, 1920

INTRODUCTORY

Making an estimate for a reinforced concrete building involves much more labor than is required in that for buildings constructed of structural steel, brick, wood, or a combination of these materials. This becomes obvious when we consider that a reinforced concrete beam is composed of certain quantities of cement, sand, crushed stone, water, reinforcement, formwork and labor, whereas a steel I-beam in place in a building represents, insofar as we are concerned, only a certain amount of structural steel and labor.

In order to estimate the cost of a reinforced concrete beam, column, floor slab, or wall it is necessary to determine the quantities of concrete, steel reinforcement, formwork, and labor involved, and to these quantities affix proper unit prices. In arriving at proper unit prices, we must still further sub-divide the amount of concrete into its constituent parts of cement, sand, and crushed stone. We must likewise determine the amount of lumber necessary properly to form the concrete, before a correct unit price for formwork may be decided upon. Again, the necessary amount of plant equipment, and the labor incidental to its installation and removal, must be carefully considered and the cost determined before the estimate is complete.

Compare with this the process of estimating the cost of a steel member in a building, which consists of so many pounds of steel and so much labor, and we may readily appreciate that accurately to estimate all the structural members of a reinforced concrete building requires much more detail work than is called for in estimating most other types of building construction.

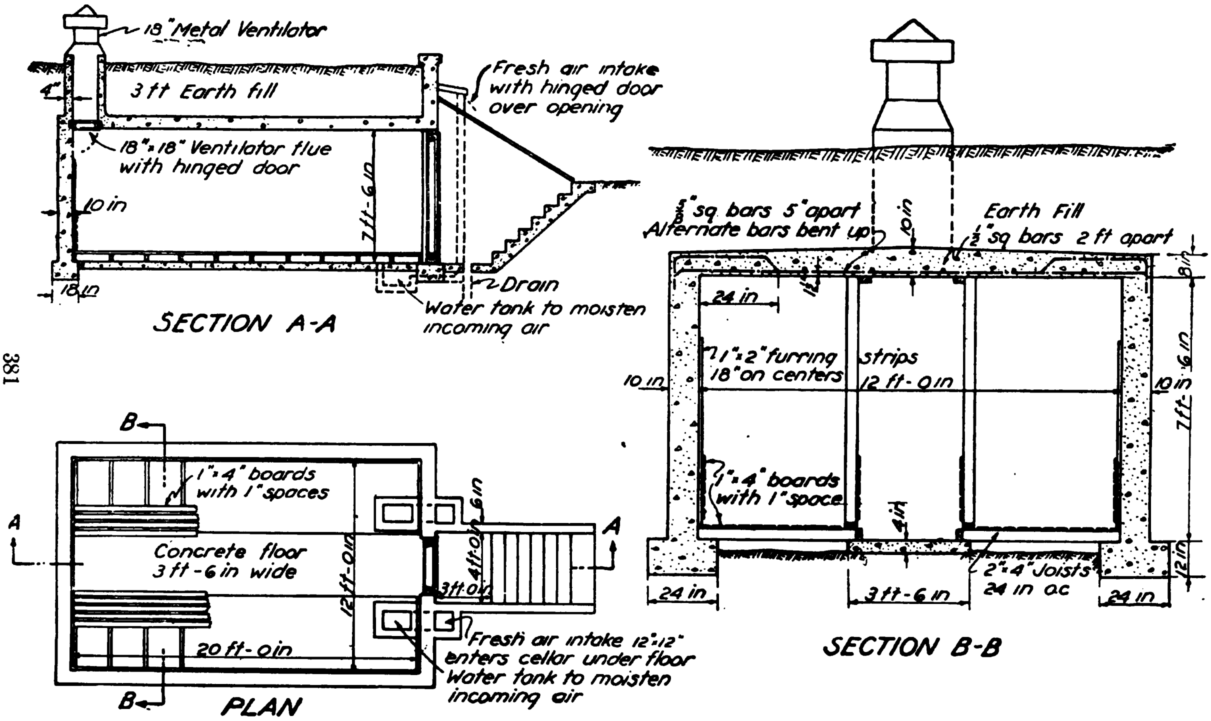

18" Metal Ventilator
4"
3 ft Earth fill
18"×18" Ventilator flue with hinged door
10 in
7 ft-6 in
18 in
Fresh air intake with hinged door over opening
Drain
Water tank to moisten incoming air
SECTION A-A
$\frac{3}{8}$" sq bars 5" apart
Alternate bars bent up
10 in
Earth Fill
$\frac{1}{2}$" sq bars 2 ft apart
8 in
24 in
1½
1"×2" furring strips
18" on centers
12 ft-0 in
10 in
10 in
7 ft-6 in
1"×4" boards with 1" space
4 in
2"×4" Joists 24 in oc
12 in
24 in
3 ft-6 in
24 in
SECTION B-B
B
1"×4" boards with 1" spaces
A
Concrete floor 3 ft-6 in wide
12 ft-0 in
4 ft-0 in
6 in
3 ft-0 in
A
20 ft-0 in
B
Fresh air intake 12"×12" enters cellar under floor
Water tank to moisten incoming air
PLAN

FIG. 207. CONCRETE STORAGE CELLAR (Courtesy of the Portland Cement Association).

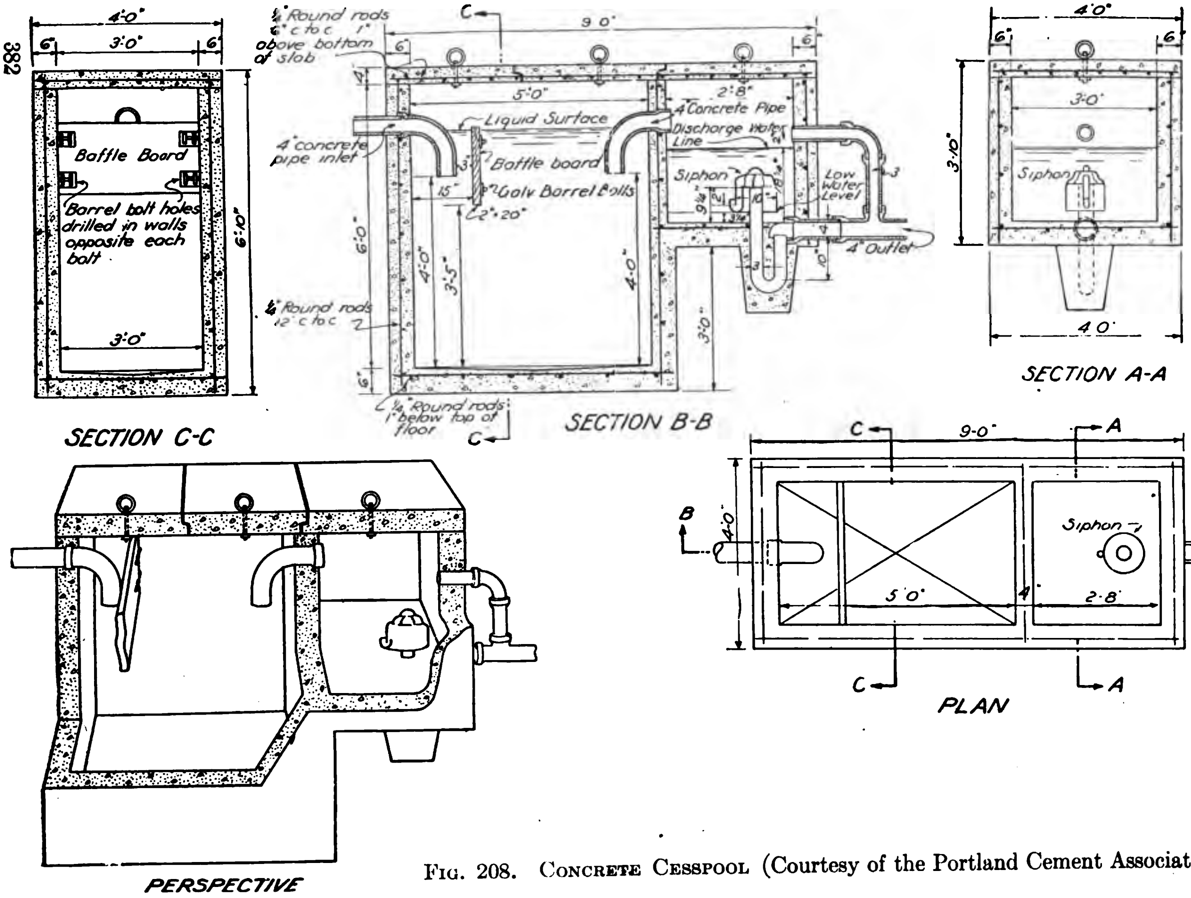


FIG. 208. CONCRETE CESSPOOL (Courtesy of the Portland Cement Association).

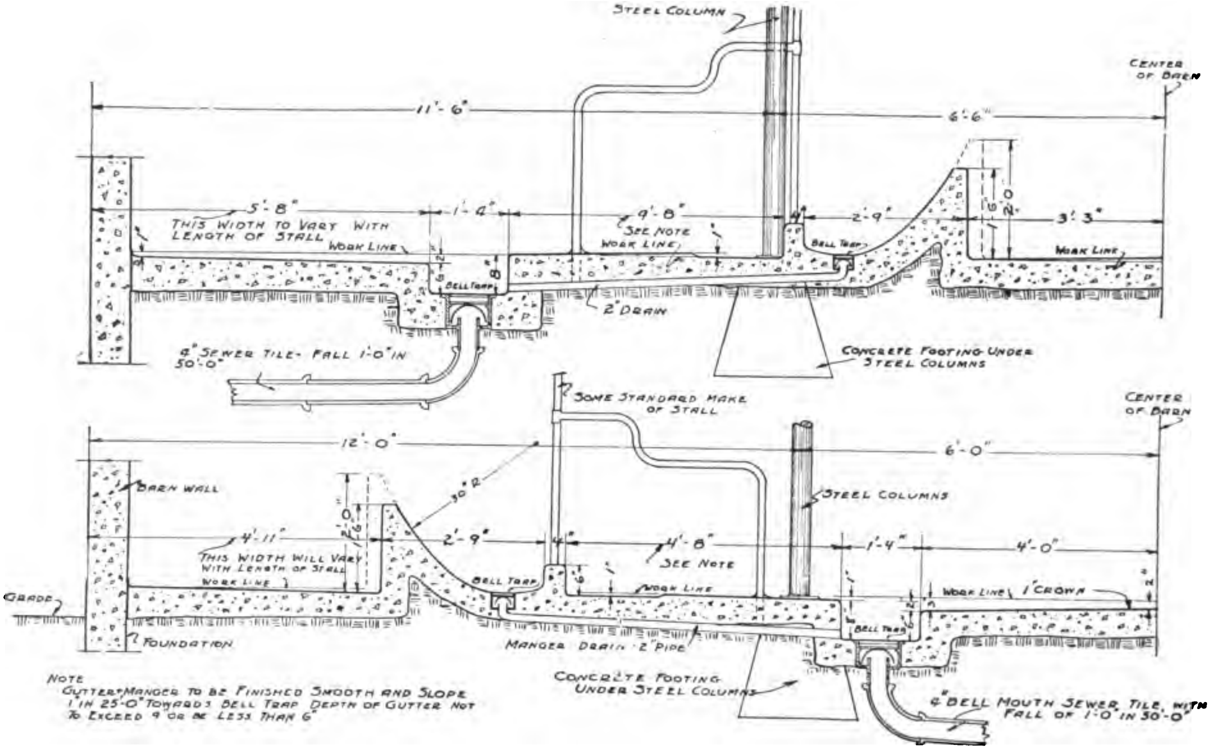
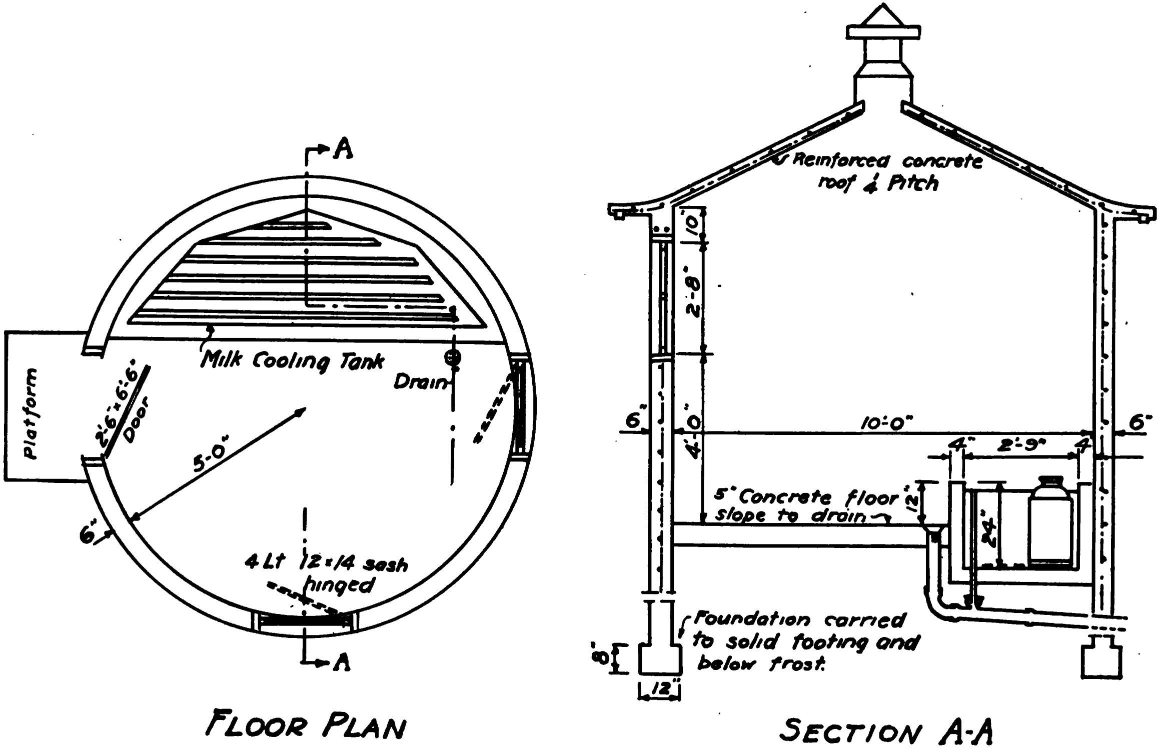

STEEL COLUMN
CENTER OF BARN
11'-6"
6'-6"
5'-8"
1'-4"
9'-8"
SEE NOTE
2'-9"
3'-3"
THIS WIDTH TO VARY WITH LENGTH OF STALL
WORK LINE
BELL TRAP
2" DRAIN
4" SEWER TILE - FALL 1'-0" IN 50'-0"
CONCRETE FOOTING UNDER STEEL COLUMNS
SOME STANDARD MAKE OF STALL
CENTER OF BARN
12'-0"
6'-0"
30" R
BARN WALL
4'-11"
2'-9"
4'-8"
SEE NOTE
1'-4"
4'-0"
STEEL COLUMNS
THIS WIDTH WILL VARY WITH LENGTH OF STALL
WORK LINE
BELL TRAP
1" CROWN
GRADE
FOUNDATION
MANGER DRAIN 2" PIPE
CONCRETE FOOTING UNDER STEEL COLUMNS
4" BELL MOUTH SEWER TILE, WITH FALL OF 1'-0" IN 30'-0"
NOTE
GUTTER & MANGER TO BE FINISHED SMOOTH AND SLOPE 1" IN 25'-0" TOWARDS BELL TRAP DEPTH OF GUTTER NOT TO EXCEED 9" OR BE LESS THAN 6"

FIG. 209. CONCRETE CATTLE BARN PAVEMENT (Courtesy of the Portland Cement Association).



FLOOR PLAN

SECTION A-A

FIG. 210. CONCRETE MILK COOLING TANK (Courtesy of the Portland Cement Association).

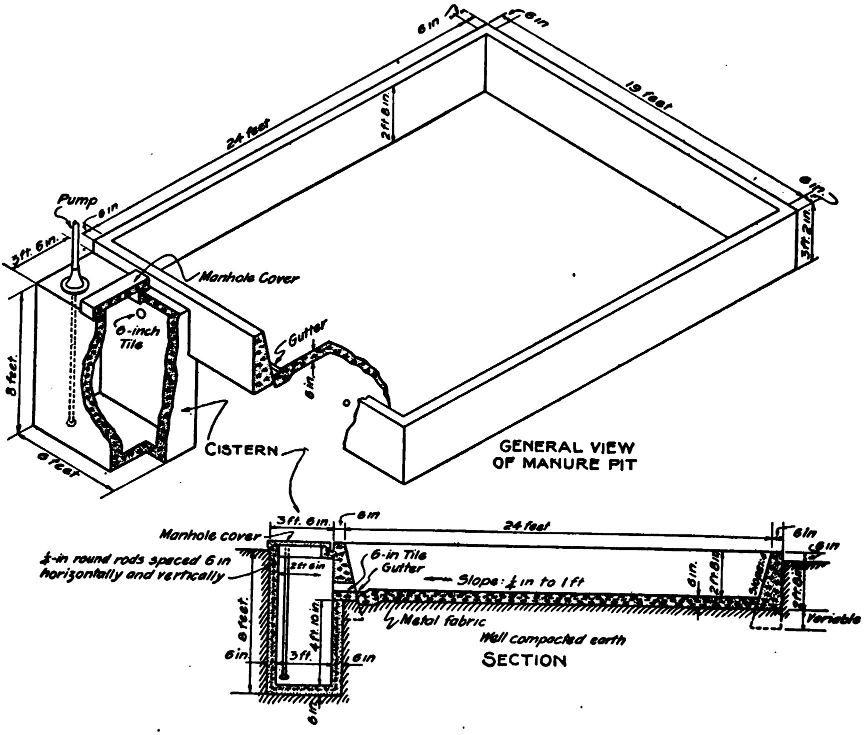


FIG. 211. CONCRETE MANURE PIT.*

* Courtesy of the Portland Cement Association.

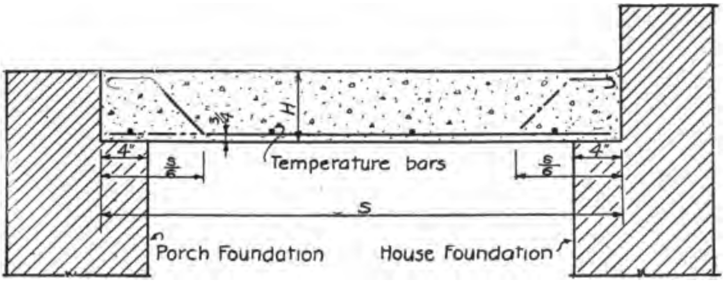


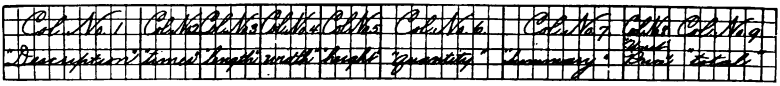
FIG. 212. PORCH SLAB CONSTRUCTION.

PART I—QUANTITIES

I. General Procedure

Scaling. In estimating the cost of a reinforced concrete building, it is essential to make a complete list of all materials and labor arranged in a convenient form, in accordance with methods which will involve the least amount of labor. In making this list, it is necessary to consider every structural member in the building from the footings to the roof slab. The quantities will be determined by carefully scaling, or making a quantity survey of the plans of the proposed building. The estimated quantities will then be priced; and the sum of the extended totals, to which have been added the cost of superintendence, liability insurance, profit, and other items common to all building operations will, if correctly figured, closely approximate the final cost of the work.

Stationery Forms. Making a scaling of the plans, as it is commonly called, is the first step in preparing an estimate. In order to perform this work rapidly and with the least possible chance for error, properly ruled stationery is essential. Paper (8½ inches × 11 inches) ruled like the copy shown below has been found of convenient design. Its use is recommended.



Col. No. 1	Col. No. 2	Col. No. 3	Col. No. 4	Col. No. 5	Col. No. 6.	Col. No. 7	Col. No. 8	Col. No. 9
"Description"	"times"	"length"	"width"	"height"	"quantity"	"summary"	"Unit Price"	"total"

Column No. 1 is the **description** column. It is used to note briefly the location and character of the work being scaled in order that future identification may easily be made.

Column No. 2 is the **times** column. In this column should be noted the number of pieces or duplicate members which are being scaled from the plans, as exactly alike. If no duplicate pieces are shown on the drawing, this column is not used and it is understood that but one member or unit is to be estimated.

Column No. 3 is the **first dimension,** or **length,** column.

Column No. 4 is the **second dimension,** or **width,** column.

Column No. 5 is the **third dimension,** or **height,** column.

Column No. 6 is the **quantity** column, and should contain the extended quantity only.

Column No. 7 is the **summary** column, in which the total of the **quantity** column is shown reduced to the unit of measure generally accepted as the standard measure ready for pricing; — as cubic yards of concrete, tons of steel reinforcement, etc.

Column No. 8 is for the **unit price.**

Column No. 9 is the **total** column, for the product obtained by multiplying the summarized quantity by the unit price. This product is carried out in even dollars.

The Order of Scaling. On account of the comparatively large number of details involved in estimating the cost of reinforced concrete construction, it is important that a definite system, or **order of scaling,** be laid out and carefully followed. When this is done, the work of scaling the plans is greatly simplified and the liability to error is reduced to a minimum. In preparing the list, or **order of scaling,** the items to be scaled should, with one or two exceptions mentioned later on, be considered in the order of actual job construction. For the convenience of the reader, a list is given below which fulfills this requirement and is easily remembered.

- **Area and cube**
  - **Concrete**
    - Exterior and interior footings
    - Foundation walls
    - Exterior columns and brackets
    - Interior columns and heads
    - Floor slabs and roof slab
    - Drop panels
    - Wall beams, parapet beams, and curtain walls
    - Interior floor beams
    - Partitions
    - Window sills (including forms and reinforcement)
    - Copings (including forms and reinforcement)
    - Stairs and stair landings (including forms and reinforcement)
    - Paving
    - Granolithic finish
    - Carborundum rubbing
  - **Forms**
    - Exterior and interior footings
    - Foundation walls
    - Exterior columns and brackets
    - Interior columns and heads
    - Floor slabs and roof slab
    - Drop panels
    - Wall beams, parapet beams, and curtain walls
    - Interior floor beams

- Partitions
- Window sills, copings, stairs and landings, etc.

Reinforcement
- (See list for forms)

Excavation
- General or steam shovel
- Hand work
- Backfill
- Sheeting

Masonry
- Brick work
- Brick veneer
- Terra cotta partitions
- Plastering

Steel sash
Glass and glazing
Doors, frames, hardware, etc.
Light iron work and miscellaneous iron
Roofing and flashing
Painting
- Walls and ceilings
- Sash and doors
- Light iron

Engineering, plans, etc.
Clean up job at completion
Liability Insurance
Watchman
Superintendence, job overhead, office, stationery, telephone, etc.
Sundries
Profit

This list is by no means exhaustive but it will serve as a sufficient outline, which may be elaborated by the addition of special items as they occur. As it stands, however, the list includes the items usually found in a typical reinforced concrete building.

The proper method of scaling the quantities in each element of the list as given is briefly discussed in the pages which follow.

II. PRELIMINARIES

Area and Cube. Preliminary to any estimate for a building there should be noted the square foot area of the floors of the building and the cubical contents of the structure.

This is done in order that the estimator may, with practice, learn to judge the cost of the work quite closely on a square and cubic foot basis before the estimate is begun. Practice of this kind, checked up after the estimate is completed, will be very helpful in developing the estimator's judgment.

In determining the area, the floors (including basements) should be measured and the dimensions taken "out to out." For instance, the area of a building two stories high, 160 feet long and 60 feet wide should appear on the estimate sheet as follows: — 2 × 160 × 60 equals 19,200 square feet.

The cubical contents of the building should be figured from the same length and width dimensions, the total height being measured from the bottom of the basement floor to the top of the roof slab. The cubical contents, or **cube,** as it is commonly called, should then appear as follows: — 160 × 60 × 23⅔ equals 227,200 cubic feet.

III. Concrete

Concrete Exterior and Interior Footings. In scaling the quantities of a concrete footing, it is necessary first to determine the amount of concrete in the footing by tabulating in the proper column of the estimate sheet the dimensions of the footing.

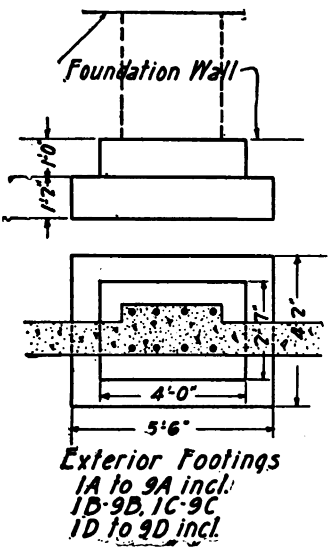


Fig. 213.

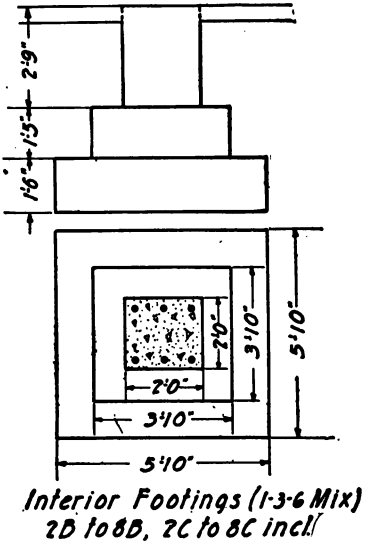


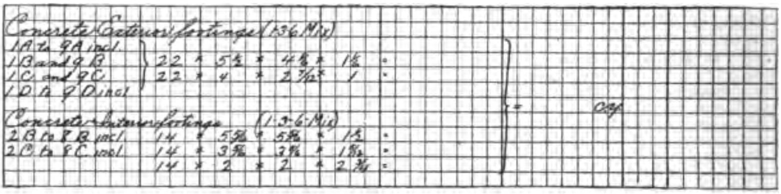
Fig. 214.

For example, Fig. 213 represents one of twenty-two typical exterior column footings for a reinforced concrete building.

First describe the footings in column No. 1 as follows:

Footing No. 1A to 9A inclusive, 1B and 9B, 1C and 9C, 1D to 9D inclusive. Next in column No. 2 note the number of footings which are alike (in this case 22). In the **length** column note the length of the lower block (5½ feet), following with the width and height dimensions (4⅛ feet and 1⅛ feet, respectively). Thus the concrete contained in the lower blocks of these 22 footings is tabulated as 22 × 5½ × 4⅛ × 1⅛.

On the line below tabulate the upper block of the footings, which will appear 22 × 4 × $2\frac{7}{12}$ × 1. The scaling of the quantities in the interior footings (Fig. 214) is handled in the same way and, when properly tabulated on the estimate sheet, appears as follows:



Concrete Exterior footings (1:3:6 Mix)
1A to 9A incl.
1B and 9B } 22 × 5½ × 4⅛ × 1⅛ =
1C and 9C } 22 × 4 × $2\frac{7}{12}$ × 1 =
1D to 9D incl.

Concrete Interior footings (1:3:6 Mix) } = C.Y.
2B to 8B incl. 14 × $5\frac{5}{12}$ × $5\frac{5}{12}$ × 1½ =
2C to 8C incl. 14 × $3\frac{5}{12}$ × $3\frac{5}{12}$ × $1\frac{5}{12}$ =
14 × 2 × 2 × 2¾ =

This completes the scaling of the concrete in the footings. It will not be necessary to refer to the plans again in order to get the form quantities in connection with these footings. This will be explained later on in the section under **Form-work.**

It will be noted that fractions are used instead of inches or decimal parts of a foot. To use inches makes extension of totals difficult and the tabulation unwieldy. To use decimals is to invite error, as the decimal point is very likely to be misplaced or omitted. Years of practice have proved that the only safe method is to use fractions of a foot when inches are indicated; no fraction to be smaller than one-twelfth ($\frac{1}{12}$).

Thus:
3 feet 5 inches = $3\frac{5}{12}$ feet
6 feet 9 inches = 6¾ feet
8 feet 10 inches = 8⅚ feet.

Where half inches are involved in concrete work (except in the thickness of floors), the fraction should be equivalent to the next higher even inches. For example:

6 feet 5½ inches = 6½ feet
7 feet 2½ inches = 7¼ feet.

This ruling can be safely followed without danger of gross error except in the case of floor thickness, which will be discussed under **Concrete Floor Slabs.**

As all hand books show the weights of steel bars in decimal parts of a pound, it will be necessary to use decimals in computing the tonnage of steel reinforcement.

The slide rule will be found of great value in extending quantities, and its intelligent use will result in both speed and accuracy. All arithmetical computations should be checked by a second person before the estimate is submitted.

Certain abbreviations are generally used to simplify the scaling of reinforced concrete. In these it will be found that reversing the order of the letters in some of the abbreviations reduces the liability to errors due to mistaking carelessly made letters placed next to figures for figures themselves. The following abbreviations have been used extensively and are recommended:

c.y. — cubic yards
s.y. — square yards
f.c. — cubic feet
s.f. — square feet
f.l. — linear feet
sqs. — squares (100 sq. ft.)
— when placed before stands for the number of units
— when placed after stands for pounds
Ddt. — deduct.

Concrete Foundation Wall. Under this heading, generally speaking, should be included all concrete walls below grade. In scaling such walls the quantity scaled should include all concrete above grade which can be correctly classed as a part of the foundation wall.

For example, a cellar wall may extend a foot or more above grade before reaching the level of the first floor, yet the part above grade will be classed as foundation wall along with the part of this wall which is built below the grade level. It is the usual practice to include under the term **foundation walls** all the concrete walls which are below the level of the first floor, and to include area walls, pit walls, etc.

Fig. 215 represents a cross section and plan of the foundation wall extending around a reinforced concrete building having a length of 160 feet and a width of 60 feet. In scaling the quantity of concrete

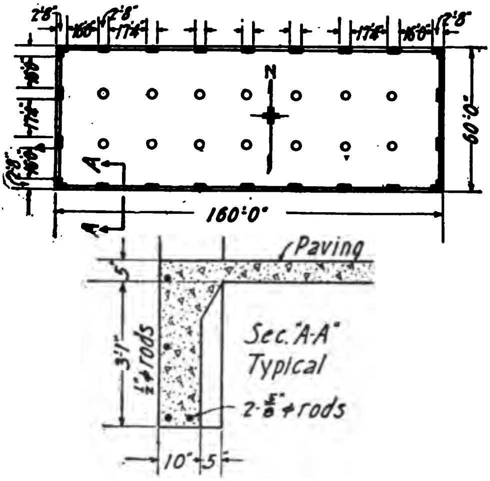
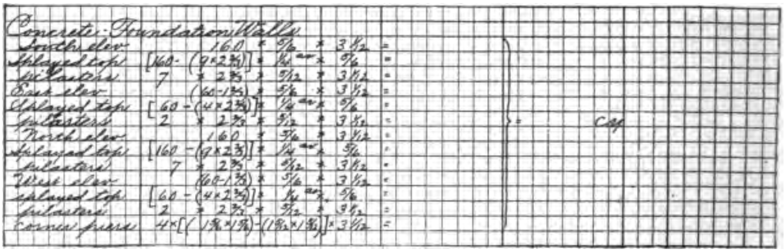


FIG. 215.

in this foundation wall the sections or pieces of wall should be considered by elevations as follows:



Concrete Foundation Walls						
South elev.	160	×	5/6	×	3 1/2	=
Splayed top	[160 − (7×2 2/3)]	×	1/4 av.	×	5/6	=
Pilasters	7 × 2 2/3	×	5/12	×	3 1/2	=
East elev.	(60 − 1 2/3)	×	5/6	×	3 1/2	=
Splayed top	[60 − (4×2 2/3)]	×	1/4 av.	×	5/6	=
Pilasters	2 × 2 2/3	×	5/12	×	3 1/2	=
North elev.	160	×	5/6	×	3 1/2	=
Splayed top	[160 − (7×2 2/3)]	×	1/4 av.	×	5/6	=
Pilasters	7 × 2 2/3	×	5/12	×	3 1/2	=
West elev.	(60 − 1 2/3)	×	5/6	×	3 1/2	=
Splayed top	[60 − (4×2 2/3)]	×	1/4 av.	×	5/6	=
Pilasters	2 × 2 2/3	×	5/12	×	3 1/2	=
Corner piers	4×[(1 5/6×1 5/6) − (1 5/12×1 5/12)]	×	3 1/2			=

} = Cy

It will be noted that in scaling the concrete foundation wall shown above, the wall on the side, or south, elevation is scaled for the full length of the elevation. The quantity of concrete in the splayed part is added as part of the foundation wall. The concrete in the 7 piers or pilasters is then added, the dimensions always being given in the order of length, width and height. Next the east or end wall is scaled (progressing anti-clockwise).

In the case of the ends, in order to avoid doubling the amount of material in the corners, the inside dimension is scaled instead of the outside "over all" dimension. This dimension should be set down in the length column to read (60–1⅔). The concrete in the two piers or pilasters is next added. The north wall is scaled similar to the south, and the west similar to the east. The concrete in the 4 corner piers is then added and the scaling for the foundation wall is complete.

Concrete Exterior and Interior Columns. Fig. 216 represents a part cross section showing the typical exterior columns of a building 160 feet long and 60 feet wide.

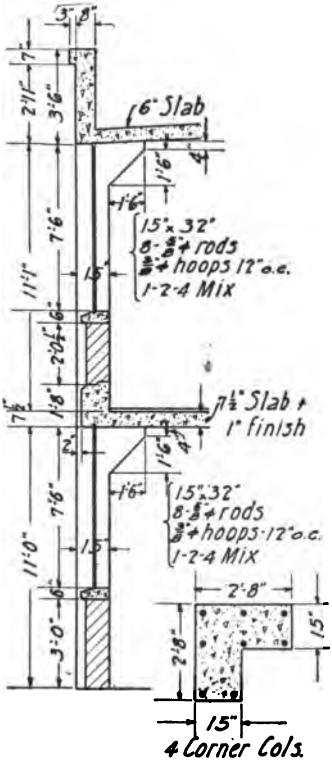


FIG. 216.

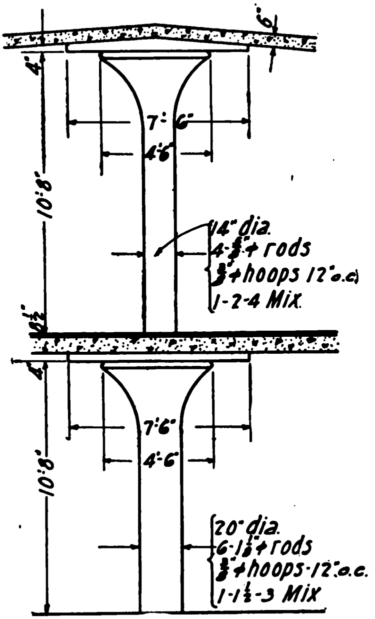
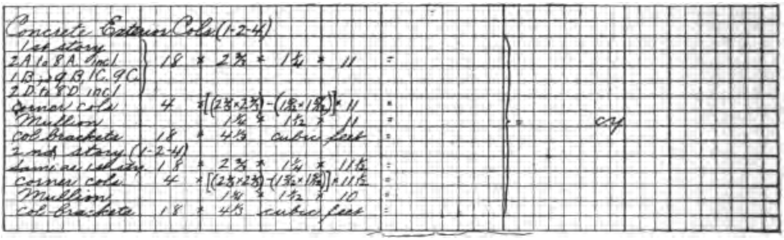


FIG. 217.

Assuming these typical columns to be spaced 20 feet apart, there will be 18 such columns in the building and 4 corner columns. The scaling of the quantity of concrete in these columns will appear as follows:



Concrete Exterior Cols (1-2-4)							
1st story							
2A to 8A incl 1B, 9B, 1C, 9C 2D to 8D incl	18	× 2⅜	× 1¼	× 11	=		
Corner cols	4	× [(2⅜×2⅜) − (1⅝×1⅝)]		× 11	=		
Mullion		1¼	× 1½	× 11	=	=	cy
Col brackets	18	× 4⅓	cubic feet		=		
2nd story (1-2-4)							
Same as 1st story	18	× 2⅜	× 1¼	× 11½	=		
Corner cols	4	× [(2⅜×2⅜) − (1⅝×1⅝)]		× 11½	=		
Mullion		1¼	× 1½	× 10	=		
Col brackets	18	× 4⅓	cubic feet		=		

Following through this scaling we have in the **times** column the number 18, which denotes the number of typical exterior columns in each story. In the next three columns of the estimate sheet are placed the length, width and height respectively of the columns being scaled.

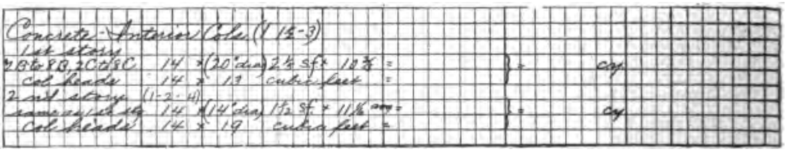
Each of the four corner columns has both exterior faces of the same dimension, but the inside corner is notched out. This complicates the expression representing the cross sectional area of the column, which is set down in the **length** and **width** columns of the estimating sheet. This expression consists of two parts. The first part represents a rectangular column and the second part represents the area of the notched portion of the column which is to be deducted from the larger area. Corner columns, or any irregular columns, should always be scaled in this manner.

The second story columns should be scaled similar to the first story columns above discussed.

As only the concrete brackets now remain to be scaled, it is necessary merely to count up the number of brackets and to determine the approximate number of cubic feet of concrete in one bracket. This completes the scaling of concrete in the exterior columns.

The scaling for the interior columns should be done in a similar manner, unless they happen to be round instead of square.

Assume that Fig. 217 represents a typical interior first and second story column of a building in which there are 14 such columns. The scaling for these 14 first story and 14 second story columns should appear as follows:

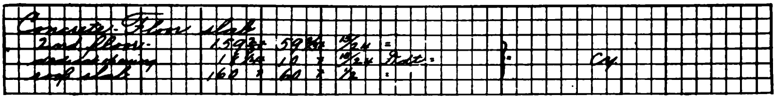


Concrete Interior Cols (1-1½-3)							
1st story							
2B to 8B, 2C to 8C	14	× (20" dia) 2¼ sf	× 10⅔	=		=	cy
Col heads	14	× 13	cubic feet	=			
2nd story (1-2-4)							
Same as 1st stg	14	× (14" dia) 1½ sf	× 11⅙	=		=	cy
Col heads	14	× 19	cubic feet	=			

In scaling the interior columns, the second column on the estimate sheet should contain the number of identical members being scaled (14 in this case). As these interior columns are round, it is not possible to use the **length** and **width** columns exactly as outlined at the beginning of this chapter. These two columns should contain, however, figures which represent the cross sectional area of the member. It is best to do this by noting the diameter of the column, enclosing same in parentheses. Immediately following should be noted in square feet the cross sectional area of the column. The **height** column should contain the length of the member from the floor to the level of the bottom of the drop panel. Next is noted in the **times** column the number of column heads (usually the same as the number of columns) and in the **length** and **width** columns the approximate number of cubic feet of concrete in the head which is in excess of the shaft already scaled. The similar tabulation of the upper story columns completes the scaling of interior column concrete.

Concrete Floor Slabs and Roof Slab. Scaling the quantity of concrete in floor and roof slabs is very simple. As in scaling the concrete for beams and columns, the dimensions should be taken off in the order of length, width, and height.

For instance, assume that it is necessary to scale the concrete in the second floor slab and roof slab of a reinforced concrete building 160 feet long and 60 feet wide. The second floor slab is 7½ inches thick, and the edge of the slab is set back 2 inches from the line of face of the building. There is a stair well opening in the slab 18¼ feet long and 10 feet wide. The roof slab is 6 inches thick and has no opening. The quantities of concrete would appear as follows:

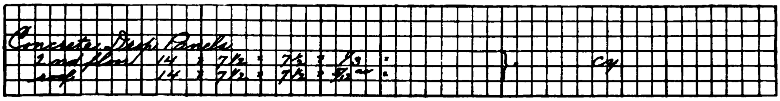


Concrete - Floor slab						
2nd Floor -	159⅔ ×	59⅔ ×	15/24	=		
Stair Opening	18¼ ×	10 ×	15/24	Deduct =	} =	C.y.
Roof slab	160 ×	60 ×	½	=		

It will be found in first practice that it is the natural tendency to put down the thickness of the slab in the **width** column instead of in the last or **height** column. This tendency will be overcome quickly if the estimator remembers that whether it is beam, column or floor slab, the order of scaling dimensions of concrete should always be length, width, and height. The thickness of the slab is a very important dimension and should be accurately tabulated on the estimate sheet. If the slab thickness is 5½ inches, the fraction tabulated in the **height** column should be 11/24. This is one of the very few instances which occur in scaling concrete work when fractions having denominators larger than 12 are recommended.

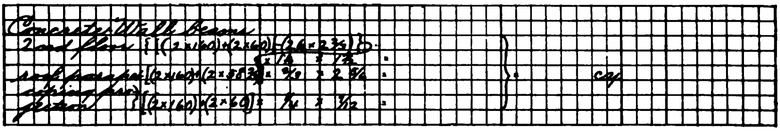
Concrete Drop Panels. Drop panels which occur over the column heads of flat slab designs should be considered as small floor or roof slabs when being scaled for estimate purposes.

The quantity of concrete in the drop panels shown under the floor slab and roof slab in Fig. 217 would appear on the estimate sheet as shown below.



Concrete Drop Panels									
2nd floor	14	×	7½	×	7½	×	[illegible]	=	} cy
roof	14	×	7½	×	7½	×	[illegible]	=	

Concrete Wall Beams. Under the heading wall beams should be included the curtain walls, parapet beams, and other similar structural members. In Fig. 216 is shown a typical wall beam and parapet beam in a building 160 feet long and 60 feet wide. The exterior columns are 20 feet apart. The concrete in the wall beams and parapet beams will appear as follows:



Concrete Wall Beams							
2nd floor	{[(2×160)+(2×60)]−(26×2⅓)}	×	[illegible]	×	[illegible]	=	
roof [illegible]	[(2×160)+(2×58⅔)]	×	[illegible]	×	2 [illegible]	=	} cy
[illegible]	{[(2×160)+(2×60)]	×	[illegible]	×	[illegible]	=	

The expression within the braces above represents the total actual length of wall beam. Within the braces we find two expressions; the first enclosed in brackets, and the last in parentheses only. The first of these represents the perimeter of the building, and the second the total length of column faces, which should be deducted from the perimeter in order to arrive at the actual total length of wall beam. The parapet is scaled in a similar manner, but no deductions are made except for overlapping corners. It will be found that errors will be avoided if wall beams, parapets, etc., are scaled in this manner. If the beams are considered individually, omissions of entire beams are very likely to occur and the error may easily be passed unnoticed.

Interior Floor Beams. Interior floor beams are usually scaled by simply noting in the description column the location or index number of the beam or beams.

The **times** column contains the number of identical beams, and the **length, width** and **height** columns are used according to the method set forth throughout the preceding pages.

The height of a beam should always be taken exclusive of the slab thickness. Beams around stair openings should be treated in the same way, except that sketches of the cross section of the beam should usually be made in the **description** column as a help in determining the formwork as indicated in the illustration below. For instance, if we have two stair well beams as shown in Fig. 218, the quantities of concrete will appear as follows:

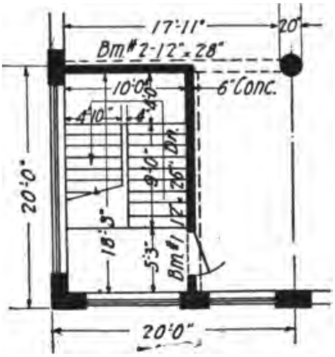
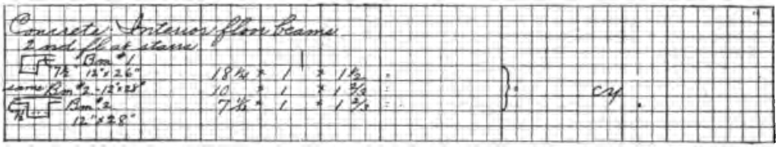


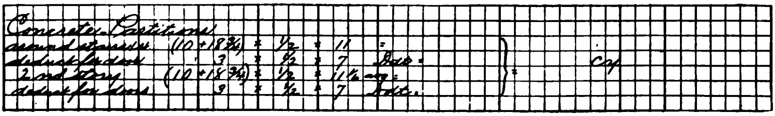
FIG. 218.



Concrete Interior floor Beams					
2nd fl at stairs					
Bm #1					
7½" 12"×26"	18¾ × 1 × 1½ =				
same Bm #2 - 12"×28"	10 × 1 × 1⅔ =	} =		cy	
Bm #2	7½ × 1 × 1⅔ =				
12"×28"					

Partitions. Concrete partitions are scaled in the same manner as interior concrete beams.

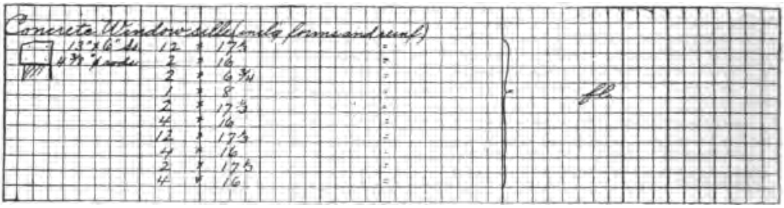
In the **description** column should be noted the approximate location or character of the partitions. The remaining columns of the estimate sheet are to be used as hereinbefore set forth. It should always be borne in mind that, in this case, the thickness of the partition is the **width** or second dimension scaled. The concrete quantities appear below for the 6-inch concrete partitions shown in Fig. 218 and occurring on the first and second floors of a building having a story height of about 11 feet.



Concrete Partitions				
around stairway	(10 + 18¾) × ½ × 11 =			
deduct for door	3 × ½ × 7 Ded =			
2nd story	(10 + 18¾) × ½ × 11½ =	} =		cy
deduct for door	3 × ½ × 7 Ded.			

Window Sills and Copings. Concrete window sills and copings are scaled by the linear foot. In taking off the quantity of each the work proceeds by elevations.

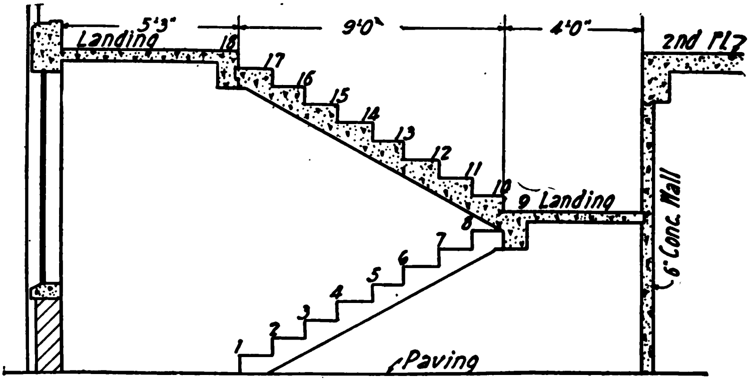
For instance, in the **description** column should appear the words "south elevation," after which should appear, in the **times** and **length** columns, the number and length of the window sills or coping on the south elevation. The east, north and west elevations should then be considered in turn. A cross sectional sketch or notation as to size of sill or coping should be made in the **description** column, as a help in determining the correct unit price per linear foot when the work of pricing the estimate is to be done. The following illustrates the proper method of scaling window sills. Should concrete copings occur on top of brick parapet walls, similar methods should be observed.



Concrete Window sills (only forms and reinf.)

13"×6" Sills 4½" [illegible]	12	×	17⅓	=
	2	×	16	=
	2	×	6¾	=
	1	×	8	=
	2	×	17⅓	=
	4	×	16	=
	12	×	17⅓	=
	4	×	16	=
	2	×	17⅓	=
	4	×	16	=

ft



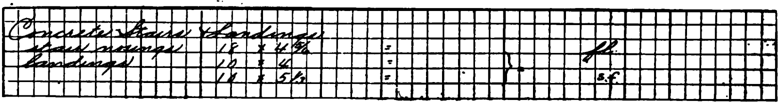
Section thru Stairs

FIG. 219.

Stairs and Landings. Fig. 219 represents the flight of reinforced concrete stairs shown in Fig. 218.

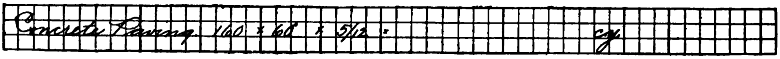
In order to scale the stairs, count the number of nosings (18 in this case), and set the number down in the **length** column. The **width** column should contain the length of each nosing from wall to outer edge. The product of the two dimensions will give the linear feet of nosing which should be taken as the standard of measure for concrete stairs.

Landings are measured by the square foot and the landing beams may be neglected, as in pricing out the cost of the landing per square foot proper allowance is made for the extra cost of the landing beam. The thickness of the landing slab may also be neglected as in the case of the stairs. Concrete stairs and landings, unless of special design, may be considered in this manner without appreciable error in cost estimating. Below is given the proper scaling of the concrete stairs and landing shown in Fig. 219 and Fig. 218.



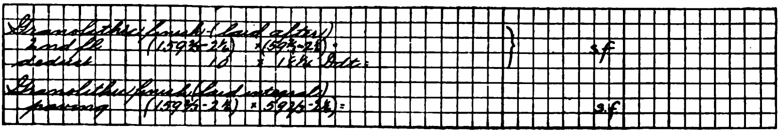
Concrete Stairs & Landings					
stair nosings	18	× 4 5/6	=		l.f.
landings	10	× 4	=	}	
	14	× 5 1/3	=		s.f.

Paving. Concrete paving is a term applied to an unreinforced concrete slab resting on earth fill, such as a basement floor or the first floor of a building where no basement is called for. In scaling the quantity of concrete in concrete paving the same rules are observed as are laid down for a concrete slab. The concrete in a piece of paving 5 inches thick and 160 feet long by 60 feet wide would appear on the estimate sheet as follows:



Concrete Paving	160	× 60	× 5/12	=	c.y.

Granolithic Finish. Scaling the quantity of granolithic finish in a building is done at this stage of the estimate because the surfaces having granolithic finish applied to them have already been scaled, and determining the quantity of granolithic finish required is simply a matter of referring to previous dimensions. For instance, if the second floor slab previously scaled is to be finished with a granolithic finish of the "laid after" type, and on the paving above an integral granolithic finish is called for, the granolithic finish dimensions would appear on the estimate sheet as follows:



Granolithic Finish (laid after)					
2nd fl.	(159 3/4 - 2 1/2)	× (59 3/4 - 2 1/2)	=	}	s.f.
deduct	10	× 12 3/4 Ditto	=		
Granolithic finish (laid integral)					
paving	(159 2/3 - 2 1/2)	× 59 2/3 - 2 1/2)	=		s.f.

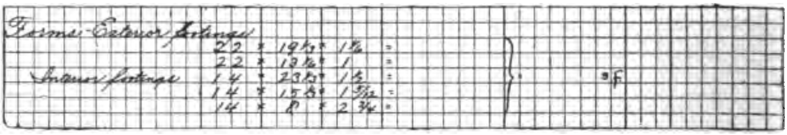
Carborundum Rubbing. The area of the surfaces to be treated with carborundum rubbing can be more easily determined if left until the formed surfaces have been determined. This will be taken up in another part of the chapter.

IV. Forms

If the foregoing rules have been carefully followed in regard to scaling concrete, the work of determining the amount of formwork necessary to mould the concrete may be very easily accomplished with virtually no further reference to the drawings.

In writing out the form dimensions, it is necessary to refer to the concrete dimensions and copy such figures as indicate the formed surfaces. As but three columns of the estimating sheet are needed in tabulating the dimensions for formwork, the second, or **times,** column is left blank and the remaining three columns used for this work. Very little **description** is needed in writing out formwork dimensions, since, in order to learn the character of the work formed, it is necessary only to turn back to the concrete scaling corresponding to the formed surfaces in question. Enough description should be given in the **description** column to make it easy to identify the form dimensions with the concrete scaling.

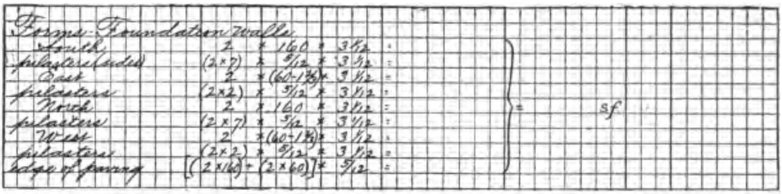
Forms for Exterior and Interior Footings. The form dimensions for the concrete footings as scaled from Fig. 214 are shown properly written out below.



Forms-Exterior footings							
	22	×	19⅓	×	1⅙	=	
	22	×	13⅓	×	1	=	
Interior footings	14	×	23⅓	×	1½	=	} F
	14	×	15⅔	×	1 5/12	=	
	14	×	8	×	2¾	=	

The first number written out is 22, and represents the number of footings being formed. The second dimension is 19⅓, and represents the perimeter of the lower block. The third dimension is 1⅙, and represents the height, in feet, of the lower block. On the next line below occur the dimensions of the formed surfaces of the upper block of the exterior footings treated in the same manner. The interior footings are treated in the same way. The product of these figures as shown will give the surfaces of concrete in the footings which must be provided with forms, and is to be priced out in the estimate as "surface measurement."

Forms for Foundation Walls. In scaling the forms for foundation walls it must be remembered that both sides of the wall are to be formed, hence the first figure written down must be the figure 2. The figures shown below represent the correct tabulation of the form dimensions for the concrete foundation wall as scaled from Fig. 215.



Forms–Foundation walls							
South	2	×	160	×	3½	=	
pilasters (sides)	(2×7)	×	5/12	×	3½	=	
East	2	×	(60–1⅔)	×	3½	=	
pilasters	(2×2)	×	5/12	×	3½	=	
North	2	×	160	×	3½	=	= sf
pilasters	(2×7)	×	5/12	×	3½	=	
West	2	×	(60–1⅔)	×	3½	=	
pilasters	(2×2)	×	5/12	×	3½	=	
edge of paving	[(2×160) + (2×60)]			×	5/12	=	

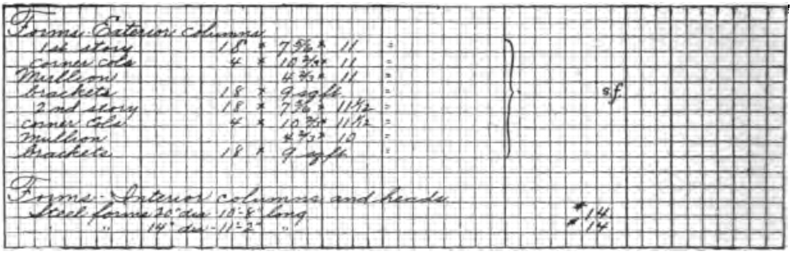
First the figure 2 denotes that two sides are formed. Next in order is stated the length of the wall to be formed, and last the height of the formwork. Both the length and height dimensions of the wall are taken directly from the concrete scaling. The piers are projections on the face of the wall; and, as the face of the pier is already measured when the face of the wall is taken, it is necessary to add only the surfaces of the edges of the piers to complete the foundation wall forms. The corner piers do not increase the amount of formed surface and may be neglected in writing out the form dimensions.

Forms, however, must be provided for the edge of the paving concrete and this is usually added to the foundation wall forms.

Forms for Exterior and Interior Columns. In writing out the form dimensions for exterior columns, and other rectangular or notched columns, the same rules are followed as have been laid down for footing forms. There are but three dimensions or numbers to write down on the estimate sheet, viz., number of columns, perimeter of column and height of the surface formed. These dimensions may be taken directly from the concrete scaling.

The forms for round columns and column heads are usually made of sheet steel or iron. Hence, instead of determining the square feet of formed surface, it is necessary only to list the number of columns formed, their diameter and height.

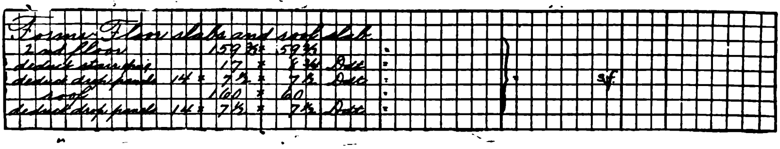
The forms for the brackets are determined by simply listing the number of brackets and determining the approximate number of square feet in one bracket. The formed surface of the bracket should be kept separate from the main column forms, as the unit price of labor is at least double for this work. Below will be found the form dimensions for the exterior and interior columns as taken from the concrete scaled from Fig. 216 and Fig. 217.



Forms Exterior columns					
1st story	18 ×	7 5/6 ×	11	=	
Corner cols	4 ×	10 3/4 ×	11	=	
Mullions		4 2/3 ×	11	=	
Brackets	18 ×	9 sq ft		=	s.f.
2nd story	18 ×	7 5/6 ×	11 1/2	=	
Corner Cols	4 ×	10 3/4 ×	11 1/2	=	
Mullion		4 2/3 ×	10	=	
Brackets	18 ×	9 sq ft		=	
Forms - Interior columns and heads					
Steel forms 30" dia 10'-8" long					#14
" 14" dia - 11'-2" "					#14

Forms for Floor Slabs and Roof Slab. In writing out the forms for flat slabs, it is necessary only to determine the area of the slab. The length and width dimensions of the slab are taken directly from the scaled dimensions of the concrete without reference to the plans. The areas of the bottoms of the drop panels should be deducted after reference to the scaling of the concrete in the drop panels. If the slab forms are for the beam and girder type of floor, the area of the slab is determined as above and then the beam bottoms are deducted from the slab areas.

To deduct the beam bottoms it is necessary to refer to the scaled dimensions of the floor beams and girders and select those dimensions which represent the bottom surfaces of all beams occurring in the floors. Deductions for openings are made from form quantities only when the area equals or exceeds 25 square feet. Even in the latter case, the full opening should not be deducted, since an allowance must be made for the formwork required to form the concrete at the edge of the opening. The forms for the concrete floor and roof slab scaled on page 392 have been properly written out below, and comparisons should be made with the concrete scaling in order fully to understand the method.



Forms Floor slabs and roof slab						
2nd floor		159 3/4 ×	59 3/4		=	
deduct stairway		17 ×	8 3/4	Ded.	=	
deduct drop panels	14 ×	7 1/2 ×	7 1/2	Ded.	=	s.f.
roof		160 ×	60		=	
deduct drop panels	14 ×	7 1/2 ×	7 1/2	Ded.	=	

Forms for Drop Panels. Drop panels are part of the floor slab concrete, and, as the areas of the bottoms of the drop panels have been deducted from the floor slab, it is necessary to restore this area again under this heading. The formed areas of the edges are also to be added to the area of the bottoms. No deduction is made for the opening in the bottom of the drop panel form where the column head joins the drop panel. The dimensions written out below represent the formed areas of the concrete in the drop panels as scaled from Fig. 217.

Forms - Drop panels			
2nd floor	14 × 7½ × 7½ =		
edge	14 × 30 × ⅓ =		
roof	14 × 7½ × 7½ =	} =	sf
edge	14 × 30 × 5/12 =		

Forms for Wall Beams. Properly to write out the forms for wall beams, curtain walls, parapet beams, etc., it is necessary to observe the rules laid down for foundation walls.

Both sides are formed, hence the necessity for placing the figure 2 before the dimension representing the linear feet of wall beam. The height of a wall beam is figured from the inside vertical height. As this leaves the outside edge of the floor slab without forms, it is necessary to add an area of formed surface equal to the perimeter of the building multiplied by the thickness of the floor slab. This takes account of all exposed surfaces to be formed, except the projecting sides of the concrete in the columns at the floor level for a height equal to the thickness of the floor slab only. This is so slight that it may be neglected. The forms for the parapet are written out following the principles outlined for wall beams. The forms for the wall beams and parapet in Fig. 216 have been properly shown below and comparisons with the corresponding concrete scaled from Fig. 216 should be made.

Forms - Wall Beams			
2nd floor	2 × {370½} × 1½ =		
edge of slab	[(2×160)+(2×60)] × ⅔ =		
roof parapet	2 × 437½ × 2 5/6 =	} =	sf
projections	440 × ¼ =		
edge of slab	[(2×160)+(2×60)] × ½ =		

Forms for Interior Floor Beams. If no sketches appear in the description column of the scaling of the concrete in the floor beams,* it is assumed that a slab of uniform thickness rests upon the beams.

The number of beams and the length of each are first written down as for other concrete members of similar structure. As the scaled dimension of the beam height is taken to the bottom of the slab only, it is quite simple to compute mentally the sum of the two side dimensions plus the bottom dimension. This represents the formed area of one linear foot of beam and should be written in the fourth, or width column of the estimate sheet. The product of these dimensions will give the area of the formed surfaces of the interior floor beams.

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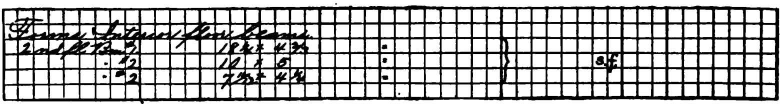
* See "Interior Floor Beams," p. 398.

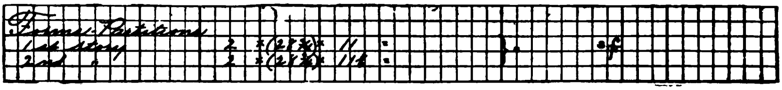
If accompanying sketches show that other formwork is necessary completely to form the beam, proper additions should be made to take care of it. The formed surfaces of the concrete as scaled in the floor beams shown in Fig. 218 are somewhat irregular, as they occur at stair openings. The quantities of this formwork appear below.



Forms Interior Floor Beams				
2nd Fl. Beams	1	18½ × 4¾	=	}
	2	12 × 5	=	} s.f.
	2	7½ × 4½	=	}

Forms for Partitions. In writing out the formed areas of concrete partitions, the same rules are observed as for other wall forms.

Openings are not deducted unless the area of the opening equals or exceeds 25 square feet. The formed areas for the concrete partitions shown in Fig. 218 are given below.



Forms Partitions				
1st story	2	× (28½) × 11	=	} s.f.
2nd "	2	× (28½) × 11½	=	}

Forms for Window Sills, Copings, Stairs, and Landings. No formed areas are written out for window sills, copings, stairs, or landings. This departure from the usual practice is justified because the unit prices per linear foot of this work are made up to include the cost of concrete, forms, reinforcement, and finish. This unit price is usually a standard one for each type of work, and is applied directly to the linear feet of work as scaled under the heading of concrete on the estimate sheets.

Formed Surfaces. Carborundum Rubbed. Referring again to the subject of carborundum rubbing, — when the form dimensions are written out, it is very simple to determine the square feet of surface to be rubbed.

This may be done very quickly by picking out from the formed areas the surfaces which, according to specification, must be treated with carborundum. It will be found most convenient to leave the work of determining the area of concrete surfaces to be rubbed until after the extension of the form dimensions has been completed. The surface measurements of all formed surfaces will then be found in the quantity column reduced to square feet, and the total area of the rubbed surfaces may be quickly determined.

V. REINFORCEMENT

Scaling the quantity of reinforcement in a concrete building is a process by which the tonnage of steel bars is obtained.

It is not necessary to make a schedule of the bars in the entire building, a process entailing a large amount of tedious work. Footing reinforcement is usually scaled by listing the size of the bars first, then the number of bars needed, and finally the length of the bar itself. Oftentimes it will be found convenient to compute the number of pounds of reinforcement in a footing and then multiply by the number of footings.

Reinforcement in foundation walls may be figured at the number of pounds per square foot of wall. Column reinforcement is usually taken off the plans in detail; the size, number of bars, and the length of the bars being taken off in regular order. Slab reinforcement is almost always computed on the square foot basis, and all beam reinforcement by the number of pounds per linear foot of beam. Curtain wall and partition reinforcement is computed by the number of pounds per square foot of reinforced surface.

In computing reinforcement on the square foot and linear foot basis, care must be taken to allow for all secondary steel, laps for bond, stirrups, construction bars, waste, etc. It will require careful practice to scale reinforcement accurately by this method, which, however, once thoroughly understood, will be found very reliable and rapid.

Reinforcement is listed in the same order as the forms. The different types may be easily grouped for pricing. The fac-simile of an estimate reproduced farther on gives a correct representation of the manner in which reinforcement should be scaled for estimating purposes.

VI. EXCAVATION

General or Steam Shovel Excavation. General excavation is the term applied to the process of removing the earth for basements, or cutting down the grade to the paving level.

General excavation does not include the excavation for footing holes below the paving level, or other small excavated areas where hand work entirely must be used. Steam shovels, scraper diggers, or hand work may be used in general excavation; and when the quantity is scaled for estimating purposes, notation should be made of the probable method to be employed in doing the work. In scaling dimensions for general excavation, the order should be the same as for scaling concrete work, viz.: length, width, and height; and these should be written down in the proper columns of the estimate sheet. Proper allowance should also be made for slope of the earth work outside of the exterior footings when the length and width dimensions are scaled. If the general excavation is done by hand, vertical sheeting may be used instead of excavating to a slope. All these conditions should be noted in the **description** column when the scaling is done.

Footing Excavation. The labor of removing earth for footing holes, pits, trenches, etc., is nearly always done by hand and should be described on the estimate sheet as **footing excavation.**

In scaling the quantities for footing excavation, the nature of the soil to be removed should be noted as well as the location of the footing hole in respect to the plans. Footing holes excavated to a depth exceeding 4 feet should be scaled net; that is, add but 6 inches to the length and width dimensions of the footing for the size of the excavated hole. This allows for the thickness of the sheeting lumber generally used in connection with footing excavation exceeding 4 feet, but not exceeding 10 feet, in depth. In scaling footing excavation when the depth is less than 4 feet, no sheeting is used; but proper allowance is made in scaling dimensions to allow for the slope of the earth work. When sheeting is used for footing excavation, the sheeting usually serves as formwork for the lower block of concrete in the footing.

Backfill. Backfill is a term applied to the labor of rehandling excavated material after the footings have been placed and it becomes necessary to fill in around the footing, wall, or other foundation work.

This quantity usually equals the amount of earth removed in excavating for the footing, as the amount of earth which is left after the footing hole is properly backfilled must be rehandled and disposed of in some other way. Where the earth work is a large part of the job operations, the backfill and general disposition of excavated material should be carefully considered.

Sheeting. Sheeting is estimated by the square feet of surface measurement of earth retained. As the form dimensions are written out from the scaled dimensions of the concrete work, so are the sheeting dimensions written out from the scaled dimensions of the excavation. No allowance is made for the distance the sheeting penetrates the ground below the bottom of the excavated hole or for the distance above the top of the earth work retained.

VII. MASONRY

Brickwork. Brickwork, where more than 4 inches thick, is estimated by the cubic foot.

In order to determine the cubic feet of brickwork in a wall, the dimensions are scaled in the same manner as outlined for **Concrete Partitions.** In scaling the brickwork in the exterior walls of a building, the work should be done by elevations, and adequate description be given to make it easy to check over the work to determine whether any part has been omitted. The quantities should contain the actual number of cubic feet of brickwork to be built and no more. All openings should be deducted exactly as they are shown, and no allowances made in the quantity to take care of work which may be more or less expensive to construct than the average unit price will pay for. After the actual cubic feet of brickwork in a building are determined, the unit price should then be made up to correspond with the class of work to be built.

Brick Veneer. Brick veneer is usually laid up 4 inches thick, and is so noted in the **description** column, together with other notations regarding the character and location of the work.

As brick veneer is estimated by the square foot in scaling the quantity, it is necessary to determine the length and height only of the work, using columns Number 4 and Number 5 in which to write down these dimensions. The work should proceed by elevations, as in the case of scaling other classes of brick work.

Terra Cotta Partitions. Partitions built from hollow terra cotta blocks are estimated by the number of blocks laid up in a wall.

As nearly all hollow terra cotta blocks have a face measurement of one square foot each, the number of blocks in the terra cotta wall corresponds to the number of square feet in the face of the partition. In scaling the square feet of terra cotta partition it is necessary to observe the same methods as were laid down for scaling **Concrete Partition.** Notation should always be made in the **description** column regarding the type of block specified and the thickness of the partition. All deductions should be accurately made. It may be stated here that the mortar joints in the work offset the usual breakage of the blocks in transit and no allowance, therefore, need be made for either mortar joints or breakage.

VIII. PLASTERING

Plastering is measured by the square yard of surface measure. The dimensions making up the quantity are usually taken directly from the scaled dimensions of the terra cotta partitions, ceilings, walls, or other surfaces in a manner similar to that in which carborundum rubbed surfaces are determined. In the **description** column are noted the number of coats called for, the kind of cement specified, and other items helpful in deciding upon proper unit prices.

IX. STEEL SASH

In estimating steel sash, the important points to consider are size of opening, uniformity of size and type, percentage of ventilation, and operation.

The **description** column should contain information relative to all these points. In scaling the size of the opening the number of identical sash should first be listed in the second column of the estimate sheet. The length and height of the openings should follow in the third and fourth columns respectively. The sash openings should be scaled by elevations, since, by this method, omissions of any magnitude are quickly noted when the dimensions are extended.

X. GLASS AND GLAZING

After noting in the **description** column the kind and size of glass specified, it is a simple matter to determine the number of square feet of glass required to glaze the sash.

For estimating purposes, it is sufficiently close to assume that 90 per cent of the sash area is made up of glass. Accordingly, the glass required is usually carried out on the estimate sheet as 90 per cent of sash area.

XI. DOORS, FRAMES, AND HARDWARE

In listing the doors, frames, and hardware in a building, the doors should be considered individually or by types.

The location and character of the door should be noted in the **description** column together with notations as to frame and hardware. In writing down the size of the door, the width should be first considered and the height last. For instance, a door 2 feet and 8 inches wide by 6 feet and 8 inches high should appear on the estimate sheet as $\frac{2}{8} \times \frac{6}{8}$. The number of doors of a kind is written down in the **summary** column as the scaling is done.

XII. LIGHT IRON WORK AND MISCELLANEOUS IRON

No special ruling can be set down governing the scaling of light iron work for general estimating purposes.

The estimator should list intelligently all such material, and at the same time endeavor to scale the dimensions in a manner which will result in the quantity being reduced to the proper basis for pricing out. Pipe hand rails should be in linear feet; safety stair treads in linear feet; steel inserts by the piece; cast-iron scuppers by the piece; and curb angle guards in linear feet at so many pounds per foot, etc. It is also customary to carry out in the **total** column a certain sum of money decided upon in the judgment of the estimator as adequate to cover miscellaneous iron work which is not shown or called for on plans or in specifications, but which must inevitably be supplied by the builder.

XIII. ROOFING AND FLASHING

The roofing dimensions are usually taken directly from the scaling of the concrete for the roof slab.

This is generally full measure, since the parapet beams reduce the roofing area slightly below the slab area. But, as roofing is measured in units of squares (100 square feet), the result is sufficiently accurate. In scaling the roofing area, it is first necessary to note in the **description** column the kind of roofing required, and the guarantee.

Flashings are a part of the roofing contract and should be scaled immediately following the roofing. Base and cap flashings are estimated by the linear foot, and notation should be made of the kind of metal specified together with the number of inches in width required to flash one linear foot. Metal **gravel strip** should be scaled in the same manner. Conductor boxes are estimated by the piece and should be listed in the **summary** column accompanied by proper description.

XIV. PAINTING

Painting of walls and ceilings is measured by the square yard, and, as in estimating the amount of carborundum rubbing, the painted surfaces may be determined by referring to the extended dimensions of the form areas of the concrete work.

Other painted work such as brick walls, terra cotta walls, etc., may be determined readily by referring to the quantities already scaled for this work and the total painted areas then reduced to square yards and written down in the **summary** column.

Painting steel sash and doors is also measured by the square yard. To determine the amount of painting on the steel sash and doors of a building, reference should be made to the scalings for the sash and doors, and the flat areas should be added together just as if the entire areas were to be painted like a door. Double these areas, since doors and sash are painted both sides. Then divide this amount by 9. The result will be the square yards of painting which should appear in the **summary** column of the estimate sheet.

Painting light iron, miscellaneous iron, etc., is usually a small item and is not figured on a square yard basis, but rather by the judgment of the estimator. The amount of money allowed for this depends entirely upon the miscellaneous iron to be painted, and each job must be considered individually.

XV. ENGINEERING, PLANS, ETC.

Sometimes the builder is called upon to include in his estimate the cost of preparing designs and plans for the work to be estimated. The percentage of cost varies with the type of building and the skill of the engineers doing the work. Ordinarily the plans of a regular reinforced concrete factory can be prepared, from the surveys to the finished drawings and details, for 3 per cent of the net cost of the completed structure.

XVI. CLEAN UP THE JOB AT COMPLETION

The estimator must allow a sum of money sufficient to cover the cost of cleaning up the job at completion, removing débris from the site, washing windows, and leaving the job "broom clean."

XVII. LIABILITY INSURANCE

An item should be included in the estimate which will cover the cost of carrying liability insurance for the period of the job.

The rate for this varies in different localities and with different contractors. The percentages may run as low as 3 per cent of the amount expended for labor; or, on the other hand, it may run as high as 12 or 14 per cent of the labor costs. As the labor expense involved in constructing a regular reinforced concrete building amounts to about one-third of the total cost of the building, the amount of money to be allowed for liability insurance premiums is easily determined when the rate is known. For instance, assume that the rate is 6 per cent of the labor and the total estimate amounts to $62,000 without profit. If this building is a regular reinforced concrete factory, the labor involved would be about one-third of $62,000, or approximately $21,000. Computing 6 per cent of $21,000, we have $1260. The amount of money carried in the estimate for liability insurance premiums could well be taken at $1250.

XVIII. WATCHMAN

In order to estimate the cost of employing a watchman while a building operation is going on, it is first necessary to determine approximately the number of weeks required to construct the building. This decided upon, it is a matter of computing the expense of employing a watchman for this length of time at a proper weekly wage.

XIX. SUPERINTENDENCE, JOB OVERHEAD, OFFICE EXPENSES, ETC.

Under this head must be included all the expense attached to maintaining a job office, including the job superintendent. It is usual custom to determine the amount of this expense for one week and to multiply this amount by the number of weeks the office must be maintained. Under the head of superintendence, office, etc., must be figured the wages of the following men:

Job Superintendent
Timekeeper
Chief office clerk
Tool boy

On unusually large jobs, the office force will consist of more men than above listed, while on a very small job the personnel may be cut down by arranging to have the chief clerk act as timekeeper in connection with his other duties. The cost of telephones, stationery, railroad fares, freight on supplies, building and dismantling office, etc., must be considered. These are items which may be easily estimated at too low a figure. Proper consideration should be given to every expense entering into overhead if the estimate is to be an accurate one in which allowance has been made for proper and competent job management.

XX. Sundries

It often occurs that estimates are made from plans not completely finished or from poorly prepared drawings. The uncertainty attached to making estimates from such plans makes it advisable to conclude the estimate with an item for sundries, the amount of which should be determined in the estimator's judgment as being adequate to protect his estimate against over-runs due to his having omitted some work implied but not shown or called for. The amount of this item should be based on a percentage of the total estimated cost not including profit, and usually runs from 2 to 5 per cent, according to the condition of the plans. It is very seldom that an estimate should be prepared without any allowance for over-runs due to unforeseen conditions.

XXI. Profit

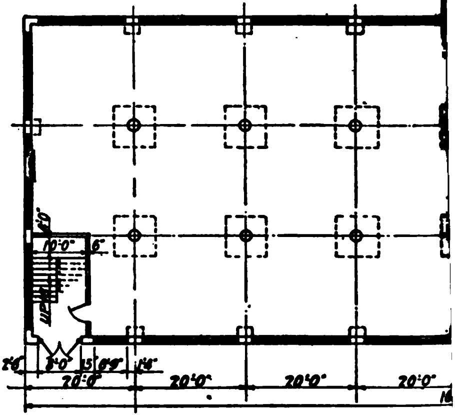
The percentage of profit is figured on the total cost of the work including labor, materials, etc.

It may be a very low percentage or it may be very high, depending entirely on the basis on which the contractor is operating his business.

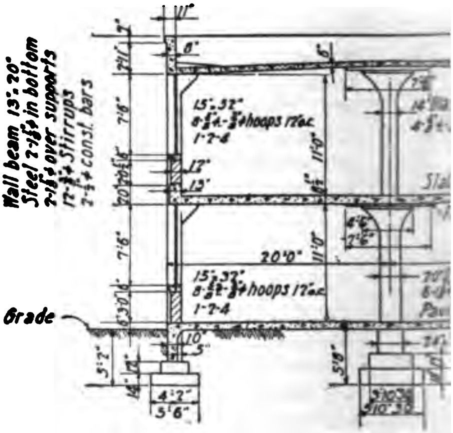
Eight per cent is considered a very low profit, and the contractor must do a large volume of business and keep his hired organization well employed in order to be successful at this rate. Percentages of profit will run from 8 to 15 per cent and sometimes higher. For ordinary estimating purposes, 10 per cent may be assumed as a fair profit for the builder of reinforced concrete buildings, unless the estimated total cost runs under $50,000, in which case 12 per cent profit should be added to the estimate.

Exemplification of Preceding Principles

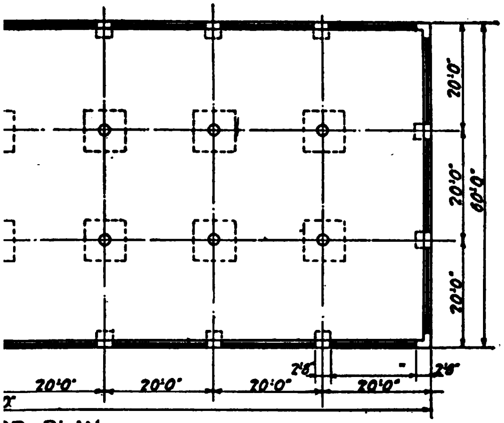
Figure 220 presents the plan and cross section of a typical, small, reinforced concrete factory, the parts of which have been already scaled in detail in the previous pages of this chapter. The necessity for condensation has made the explanations brief. Hence the reader's initiative must be depended upon for further study of the subject at hand and for the discovery of the best ways of attacking problems in estimating not here covered. The principles outlined, however, have been tested by many years of use in a large Boston Company operating extensively in the reinforced concrete field. The many advantages to be gained by their application have been conclusively proved. A fac-simile of the completed estimate


10'0"
6"
2'6"
3'0"
20'0"
20'0"
20'0"
20'0"

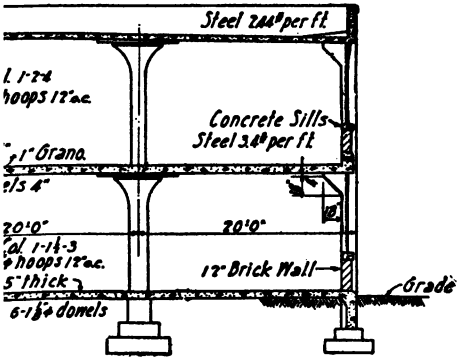
FIRST FL


Wall beam 13"×20"
Steel 2-1⅛"φ in bottom
2-1⅛"φ over supports
17-⅜"φ Stirrups
2-⅜"φ const. bars
11"
8"
6"
7'6"
7'6"
15"×32"
8-⅝"φ-⅜"φ hoops 12"o.c.
1-2-4
11'0"
12"
13"
20'0"
15"×32"
8-⅝"φ-⅜"φ hoops 12"o.c.
1-2-4
Grade
10"
5"
5'2"
14"
4'2"
5'6"
5'8"
4'6"
7'6"

CRO



R PLAN



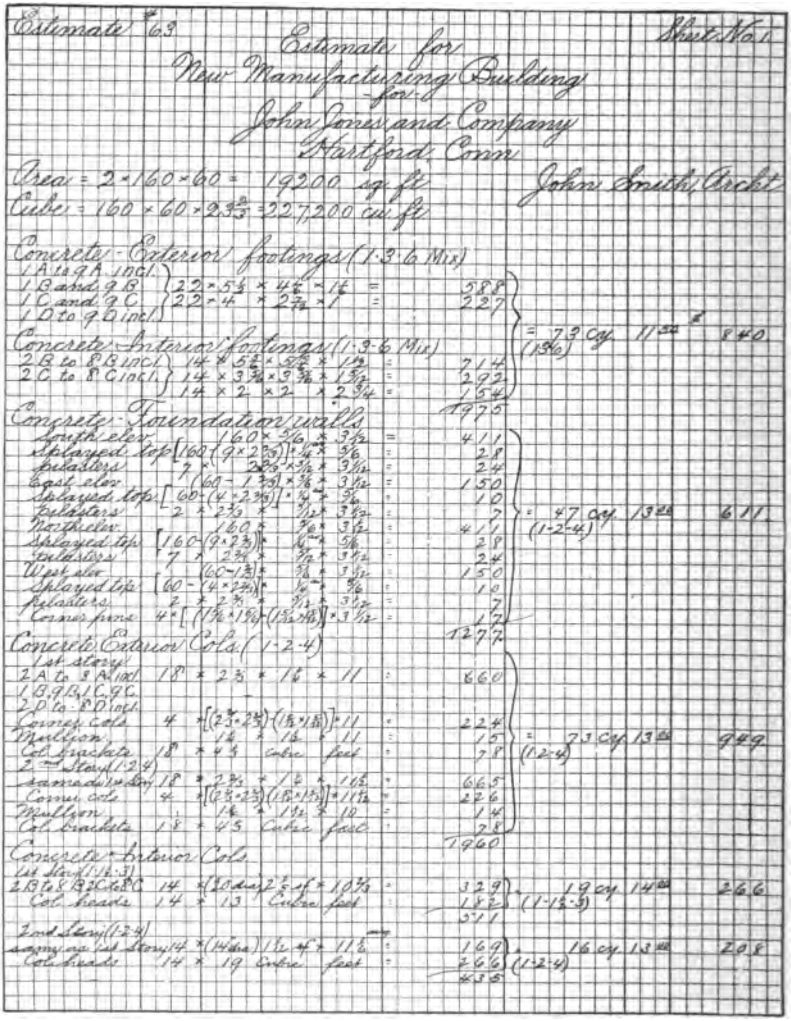
SECTION

. 220.

for the building illustrated in Fig. 220 is shown herewith. It will be noted that the scalings are identical with those discussed on the previous pages. The quantities have been extended, unit prices affixed, and the totals carried out, thus constituting as a whole the finished estimate for the construction of the building proper. The determination of unit prices is considered in Part II.

FAC-SIMILE OF THE COMPLETED ESTIMATE FOR A CONCRETE BUILDING

(Compare with Fig. 220)



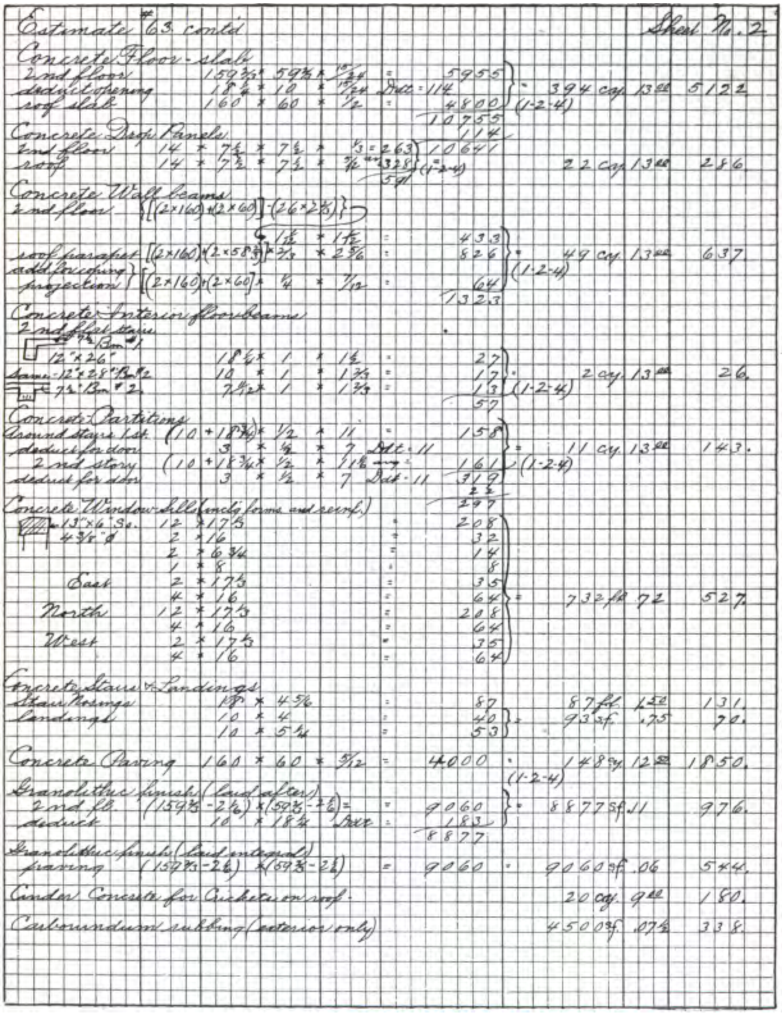
Estimate #63 Sheet No. 1

Estimate for
New Manufacturing Building
-for-
John Jones and Company
Hartford, Conn.

Area = $2 \times 160 \times 60 = 19200$ sq. ft. John Smith, Archt.
Cube = $160 \times 60 \times 23\frac{2}{3} = 227,200$ cu. ft.

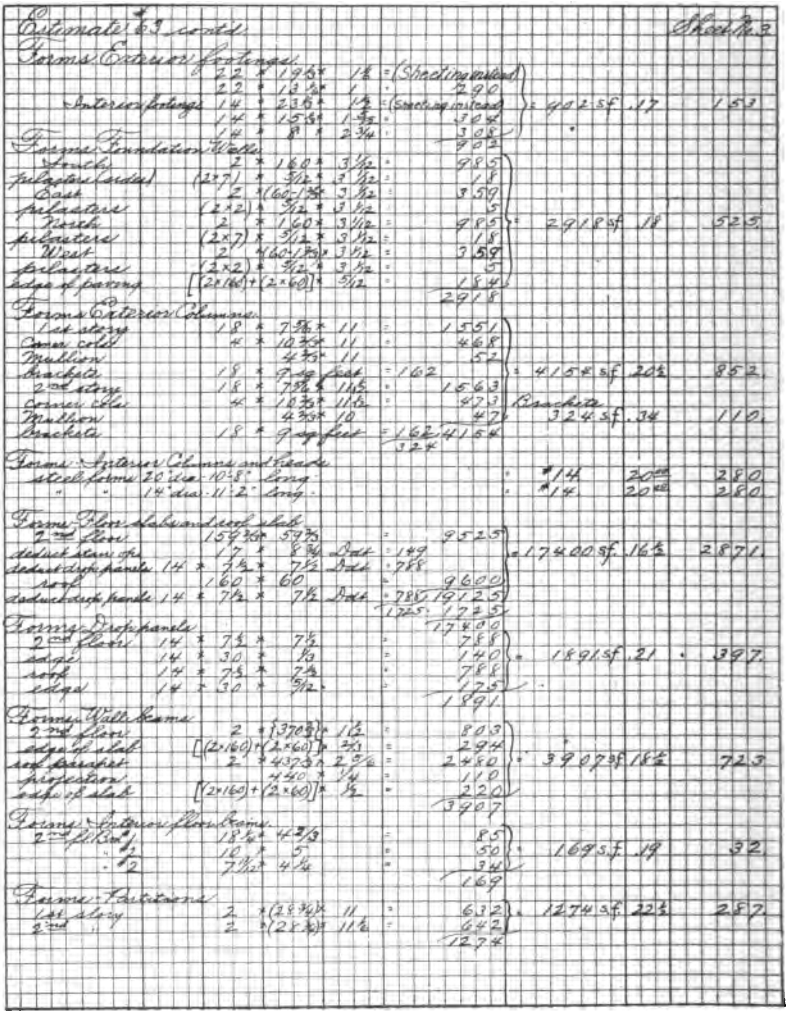
Concrete - Exterior footings (1:3:6 Mix)					
1A to 9A incl. 1B and 9B	$22 \times 5\frac{1}{2} \times 4\frac{1}{2} \times 1\frac{1}{12}$ =	588			
1C and 9C 1D to 9D incl.	$22 \times 4 \times 2\frac{7}{12} \times 1$ =	227	= 73 cy. (1:3:6)	11.50	840
Concrete Interior footings (1:3:6 Mix)					
2B to 8B incl.	$14 \times 5\frac{2}{3} \times 5\frac{2}{3} \times 1\frac{7}{12}$ =	714			
2C to 8C incl.	$14 \times 3\frac{5}{6} \times 3\frac{5}{6} \times 1\frac{5}{12}$ =	292			
	$14 \times 2 \times 2 \times 2\frac{3}{4}$ =	154			
		1975			
Concrete - Foundation walls					
South elev.	$160 \times \frac{5}{6} \times 3\frac{1}{12}$ =	411			
Splayed top	$[160 - (9 \times 2\frac{2}{3})] \times \frac{1}{4} \times \frac{5}{6}$ =	28			
pilasters	$7 \times 2\frac{2}{3} \times \frac{5}{12} \times 3\frac{1}{12}$ =	24			
East elev.	$(60 - 1\frac{2}{3}) \times \frac{5}{6} \times 3\frac{1}{12}$ =	150			
Splayed top	$[60 - (4 \times 2\frac{2}{3})] \times \frac{1}{4} \times \frac{5}{6}$ =	10			
pilasters	$2 \times 2\frac{2}{3} \times \frac{5}{12} \times 3\frac{1}{12}$ =	7	= 47 cy. (1:2:4)	13.00	611
North elev.	$160 \times \frac{5}{6} \times 3\frac{1}{12}$ =	411			
Splayed top	$[160 - (9 \times 2\frac{2}{3})] \times \frac{1}{4} \times \frac{5}{6}$ =	28			
pilasters	$7 \times 2\frac{2}{3} \times \frac{5}{12} \times 3\frac{1}{12}$ =	24			
West elev.	$(60 - 1\frac{2}{3}) \times \frac{5}{6} \times 3\frac{1}{12}$ =	150			
Splayed top	$[60 - (4 \times 2\frac{2}{3})] \times \frac{1}{4} \times \frac{5}{6}$ =	10			
pilasters	$2 \times 2\frac{2}{3} \times \frac{5}{12} \times 3\frac{1}{12}$ =	7			
Corner piers	$4 \times [(1\frac{5}{6} \times 1\frac{5}{6}) - (1\frac{5}{12} \times 1\frac{5}{12})] \times 3\frac{1}{12}$ =	17			
		1277			
Concrete Exterior Cols. (1:2:4)					
1st story					
2A to 8A incl. 1B, 9B, 1C, 9C 2D to 8D incl.	$18 \times 2\frac{2}{3} \times 1\frac{1}{4} \times 11$:	660			
Corner Cols.	$4 \times [(2\frac{2}{3} \times 2\frac{2}{3}) - (1\frac{5}{12} \times 1\frac{5}{12})] \times 11$ =	224			
Mullion	$1\frac{1}{6} \times 1\frac{1}{6} \times 11$ =	15	= 73 cy. (1:2:4)	13.00	949
Col. brackets	$18 \times 4\frac{1}{3}$ cubic feet =	78			
2nd Story (1:2:4)					
same as 1st Story	$18 \times 2\frac{2}{3} \times 1\frac{1}{4} \times 11\frac{1}{12}$ =	665			
Corner cols.	$4 \times [(2\frac{2}{3} \times 2\frac{2}{3}) - (1\frac{5}{12} \times 1\frac{5}{12})] \times 11\frac{1}{12}$ =	226			
Mullion	$1\frac{1}{6} \times 1\frac{1}{6} \times 10$ =	14			
Col. brackets	$18 \times 4\frac{1}{3}$ Cubic feet :	78			
		1960			
Concrete - Interior Cols.					
1st Story (1:1½:3)					
2B to 8B, 2C to 8C	$14 \times$ (20" dia.) $2\frac{1}{5}$ sf $\times 10\frac{2}{3}$ =	329	= 19 cy. (1:1½:3)	14.00	266
Col. heads	14×13 Cubic feet :	182			
		511			
2nd Story (1:2:4)					
same as 1st Story	$14 \times$ (14" dia.) $1\frac{1}{12}$ sf $\times 11\frac{1}{12}$:	169	= 16 cy. (1:2:4)	13.00	208
Col. heads	14×19 Cubic feet =	266			
		435			

The Completed Estimate (*Continued*)



Estimate #63 cont'd					Sheet No. 2
Concrete Floor-slab					
2nd floor	159 2/3 × 59 2/3 × 15/24 =	5955	= 394 cy. (1-2-4)	13.00	5122
deduct opening	18 3/4 × 10 × 15/24	Ddt = 114			
roof slab	160 × 60 × 1/2 =	4800			
		10755 114 10641			
Concrete Drop Panels					
2nd floor	14 × 7 1/2 × 7 1/2 × 1/3 =	263			
roof	14 × 7 1/2 × 7 1/2 × 5/12 =	328 591	22 cy. (1-2-4)	13.00	286
Concrete Wall beams					
2nd floor	{[(2×160)+(2×60)]−(26×2 1/3)} × 1 1/12 × 1 1/2 =	433			
roof parapet	[(2×160)+(2×58 2/3)] × 2/3 × 2 5/6 =	826	= 49 cy. (1-2-4)	13.00	637.
add for coping projection	[(2×160)+(2×60)] × 1/4 × 7/12 =	64 1323			
Concrete Interior floor beams					
2nd flat stair 7 1/2" Bm #1 12"×26"	18 3/4 × 1 × 1 1/2 =	27			
Same 12"×28" Bm #2	10 × 1 × 1 2/3 =	17	= 2 cy. (1-2-4)	13.00	26.
7 1/2" Bm #2	7 1/2 × 1 × 1 2/3 =	13 57			
Concrete Partitions					
Around stairs 1st.	(10 + 18 3/4) × 1/2 × 11 =	158			
deduct for door	3 × 1/2 × 7 Ddt. 11		= 11 cy. (1-2-4)	13.00	143.
2nd story	(10 + 18 3/4) × 1/2 × 11 1/6 =	161			
deduct for door	3 × 1/2 × 7 Ddt. 11	319 22 297			
Concrete Window Sills (incl'g forms and reinf.)					
13"×4" Sq. 4 3/8" ø	12 × 17 1/3 =	208			
	2 × 16 =	32			
	2 × 6 3/4 =	14			
	1 × 8 =	8			
East	2 × 17 1/3 =	35			
	4 × 16 =	64	= 732 ft.	.72	527.
North	12 × 17 1/3 =	208			
	4 × 16 =	64			
West	2 × 17 1/3 =	35			
	4 × 16 =	64			
Concrete Stairs & Landings					
Stair Nosings	18 × 4 5/6 =	87	87 ft.	1.50	131.
landings	10 × 4 =	40	= 93 sf.	.75	70.
	10 × 5 1/4 =	53			
Concrete Paving	160 × 60 × 5/12 =	4000	= 148 cy. (1-2-4)	12.50	1850.
Granolithic finish (laid after)					
2nd fl.	(159 2/3 − 2 1/6) × (59 2/3 − 2 1/6) =	9060	= 8877 sf.	.11	976.
deduct	10 × 18 1/4 Ddt =	183 8877			
Granolithic finish (laid integral)					
paving	(159 2/3 − 2 1/6) × (59 2/3 − 2 1/6) =	9060	= 9060 sf.	.06	544.
Cinder Concrete for Crickets on roof			20 cy.	9.00	180.
Carborundum rubbing (exterior only)			4500 sf.	.07 1/2	338.

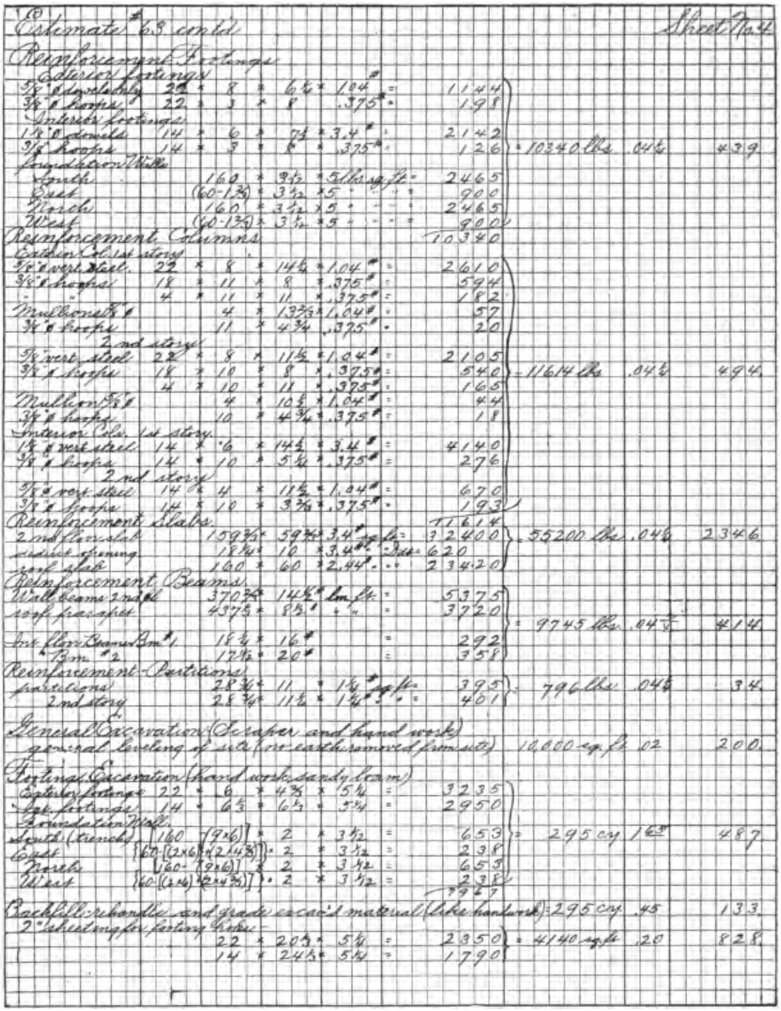
The Completed Estimate (*Continued*)



Estimate #63 cont'd. Sheet No. 3

Forms Exterior footings						
	22 × 19⅔ × 1½	= (Sheeting instead)				
	22 × 13⅓ × 1	=	290			
Interior footings	14 × 23⅓ × 1½	= (Sheeting instead)		= 902 sf	.17	153
	14 × 15⅓ × 1 5/12	=	304			
	14 × 8 × 2¾	=	308			
			902			
Forms Foundation Walls						
South	2 × 160 × 3 1/12	=	985			
pilasters (sides)	(2×7) × 5/12 × 3 1/12	=	18			
East	2 × (60-1⅔) × 3 1/12	=	359			
pilasters	(2×2) × 5/12 × 3 1/12	=	5			
North	2 × 160 × 3 1/12	=	985	= 2918 sf	.18	525
pilasters	(2×7) × 5/12 × 3 1/12	=	18			
West	2 × (60-1⅔) × 3 1/12	=	359			
pilasters	(2×2) × 5/12 × 3 1/12	=	5			
edge of paving	[(2×160)+(2×60)] × 5/12	=	184			
			2918			
Forms Exterior Columns						
1st story	18 × 7 5/6 × 11	=	1551			
Corner cols	4 × 10⅔ × 11	=	468			
Mullion	4¾ × 11		52			
brackets	18 × 9 sq feet	= 162		= 4154 sf	20½	852
2nd story	18 × 7 5/6 × 11 1/12	=	1563			
corner cols	4 × 10⅔ × 11 1/12	=	473	Brackets		
Mullion	4⅔ × 10		47	324 sf	.34	110
brackets	18 × 9 sq feet	= 162	4154			
		324				
Forms Interior Columns and heads						
steel forms 20" dia. 10'-8" long				= #14	20.00	280
" " 14" dia. 11'-2" long				= #14	20.00	280
Forms Floor slabs and roof slab						
2nd floor	159⅝ × 59⅔	=	9525			
deduct stair opg.	17 × 8¾ Ded.	= 149		= 17400 sf	16½	2871
deduct drop panels	14 × 7½ × 7½ Ded.	= 788				
roof	160 × 60	=	9600			
deduct drop panels	14 × 7½ × 7½ Ded.	= 788	19125			
		1725	1725			
			17400			
Forms Drop panels						
2nd floor	14 × 7½ × 7½	=	788			
edge	14 × 30 × ⅓	=	140	= 1891 sf	.21	397
roof	14 × 7½ × 7½	=	788			
edge	14 × 30 × 5/12	=	175			
			1891			
Forms Wall beams						
2nd floor	2 × {370⅔} × 1 1/12	=	803			
edge of slab	[(2×160)+(2×60)] × ⅔	=	294			
roof parapet	2 × 437⅓ × 2 5/6	=	2480	= 3907 sf	18½	723
projection	440 × ¼	=	110			
edge of slab	[(2×160)+(2×60)] × ½	=	220			
			3907			
Forms Interior floor beams						
2nd fl. Bm. 1	18¼ × 4⅔	=	85			
" 2	10 × 5	=	50	= 169 s.f.	.19	32
" 2	7 7/12 × 4½	=	34			
			169			
Forms Partitions						
1st story	2 × (28¾) × 11	=	632	= 1274 sf	22½	287
2nd "	2 × (27⅞) × 11½	=	642			
			1274			

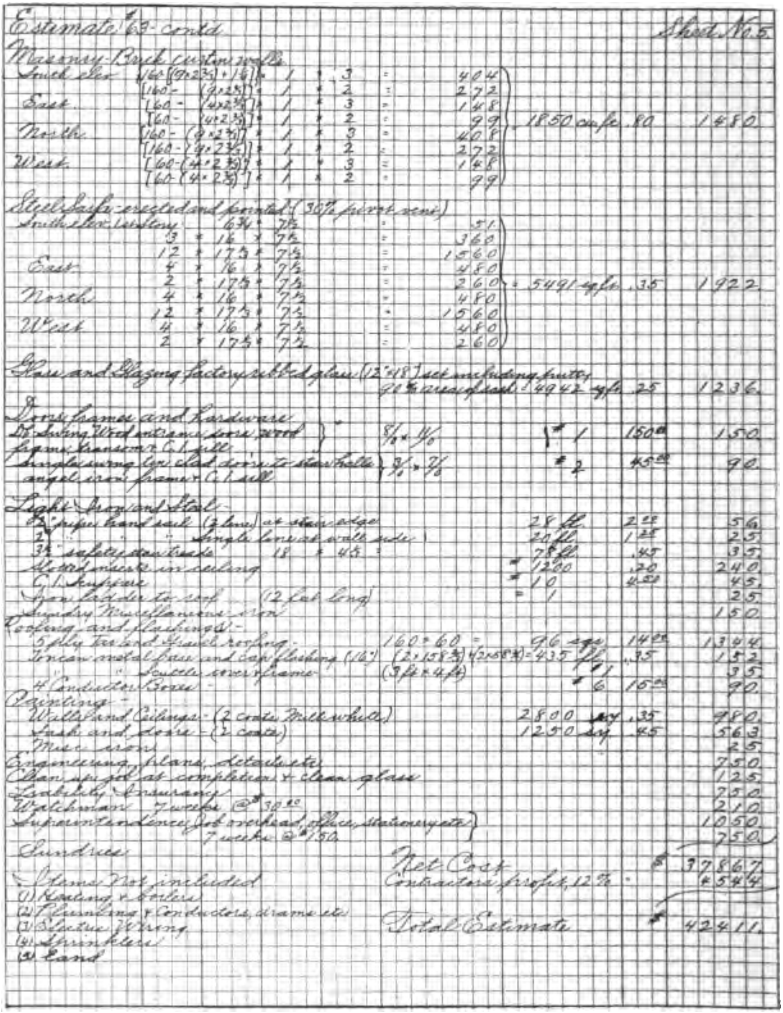
The Completed Estimate (*Continued*)



Estimate #63 cont'd — Sheet No. 4

Item	Calculation	Quantity	Total	Rate	Amount
Reinforcement Footings					
Exterior footings					
⅝" ø dowels only	22 × 8 × 6¼ × 1.04# =	1144			
⅜" ø hoops	22 × 3 × 8 × .375# =	198			
Interior footings					
1⅛" ø dowels	14 × 6 × 7½ × 3.4# =	2142			
⅜" ø hoops	14 × 3 × 8 × .375# =	126	= 10340 lbs	.04¼	439
Foundation Walls					
South	160 × 3½ × 5 lbs sq ft =	2465			
East	(60 − 1⅓) × 3½ × 5 " " " =	900			
North	160 × 3½ × 5 " " " =	2465			
West	(60 − 1⅓) × 3½ × 5 " " " =	900			
		10340			
Reinforcement Columns					
Exterior Col. 1st story					
⅝" ø vert. steel	22 × 8 × 14¼ × 1.04# =	2610			
⅜" ø hoops	18 × 11 × 8 × .375# =	594			
" "	4 × 11 × 11 × .375# =	182			
Mullions ⅝" ø	4 × 13⅔ × 1.04# =	57			
⅜" ø hoops	11 × 4¾ .375# =	20			
2nd story					
⅝" vert. steel	22 × 8 × 11½ × 1.04# =	2105			
⅜" ø hoops	18 × 10 × 8 × .375# =	540	= 11614 lbs	.04¼	494
	4 × 10 × 11 × .375# =	165			
Mullion ⅝" ø	4 × 10⅛ × 1.04# =	44			
⅜" ø hoops	10 × 4¾ × .375# =	18			
Interior Cols. 1st story					
1⅛" ø vert. steel	14 × 6 × 14½ × 3.4# =	4140			
⅜" ø hoops	14 × 10 × 5½ × .375# =	276			
2nd story					
⅝" ø vert. steel	14 × 4 × 11½ × 1.04# =	670			
⅜" ø hoops	14 × 10 × 3⅔ × .375# =	193			
		11614			
Reinforcement Slabs					
2nd floor slab	159⅔ × 59⅔ × 3.4# sq ft =	32400			
deduct opening	18¼ × 10 × 3.4# = Ded.	620	= 55200 lbs	.04¼	2346
roof slab	160 × 60 × 2.44# = " "	23420			
Reinforcement Beams					
Wall beams 2nd fl.	370¾ × 14½# lin. ft =	5375			
roof parapet	437⅓ × 8½# " " =	3720	= 9745 lbs	.04¼	414
Int. floor Beams Bm #1	18¼ × 16# =	292			
" Bm #2	17⅞ × 20# =	358			
Reinforcement Partitions					
partitions	28¾ × 11 × 1¼# sq ft	395	= 796 lbs	.04¼	34
2nd story	28¾ × 11½ × 1¼# " " =	401			
General Excavation (Scraper and hand work)					
general leveling of site (no earth removed from site)			10,000 sq ft	.02	200
Footing Excavation (hand work, sandy loam)					
Exterior footings	22 × 6 × 4⅔ × 5¼ =	3235			
Int. footings	14 × 6⅓ × 6⅓ × 5¼ =	2950			
Foundation Wall					
South (trench)	[160 − (9×6)] × 2 × 3½ =	653	= 295 cy	1.65	487
East	{60 − [(2×6) + (2×4⅔)]} × 2 × 3½ =	238			
North	[160 − (9×6)] × 2 × 3½ =	653			
West	{60 − [(2×6) + (2×4⅔)]} × 2 × 3½ =	238			
		7967			
Backfill, rehandle and grade excav'd material (like handwork)			= 295 cy	.45	133
2" sheeting for footing holes					
	22 × 20⅓ × 5¼ =	2350	= 4140 sq ft	.20	828
	14 × 24⅓ × 5¼ =	1790			

THE COMPLETED ESTIMATE (*Concluded*)



Estimate #63 - contd — Sheet No. 5

Masonry - Brick curtain walls					
South elev.	[160-[(9×2⅔)+1⅓]] × 1 × 3	= 404			
	[160-(9×2⅔)] × 1 × 2	= 272			
East	[60-(4×2⅔)] × 1 × 3	= 148			
	[60-(4×2⅔)] × 1 × 2	= 99	1850 cu.ft.	.80	1480
North	[160-(9×2⅔)] × 1 × 3	= 408			
	[160-(9×2⅔)] × 1 × 2	= 272			
West	[60-(4×2⅔)] × 1 × 3	= 148			
	[60-(4×2⅔)] × 1 × 2	= 99			
Steel Sash - erected and painted (30% pivot vent)					
South elev. 1st story	6¾ × 7½	= 51			
	3 × 16 × 7½	= 360			
	12 × 17⅓ × 7½	= 1560			
East	4 × 16 × 7½	= 480			
	2 × 17⅓ × 7½	= 260	= 5491 sq.ft.	.35	1922
North	4 × 16 × 7½	= 480			
	12 × 17⅓ × 7½	= 1560			
West	4 × 16 × 7½	= 480			
	2 × 17⅓ × 7½	= 260			
Glass and Glazing factory ribbed glass (12"×18") set including putty	90% area of sash		= 4942 sq.ft.	.25	1236
Doors frames and hardware					
Dbl. Swing Wood entrance doors, wood frame, transom & C.I. sill	8/0 × 11/0		#1	150.00	150
Single swing tin clad doors to stair halls, angle iron frame & C.I. sill	3/0 × 7/0		#2	45.00	90
Light Iron and Steel -					
1½" pipe hand rail (2 lines) at stair edge			28 ft.	2.00	56
1" " " single line at wall side			20 ft.	1.25	25
3½" safety stair treads	18 × 4⅓ =		78 ft.	.45	35
Slotted inserts in ceiling			#1200	.20	240
C.I. Scuppers			#10	4.50	45
Iron ladder to roof (12 feet long)			#1		25
Sundry Miscellaneous iron					150
Roofing and flashings -					
5 ply Tar and Gravel roofing -	160 × 60 =		96 sqs.	14.00	1344
Tin can metal base and cap flashing (16")	(2×158⅔)+(2×58⅔) =		435 ft.	.35	152
" " Scuttle cover & frame	(3 ft × 4 ft)		#1		35
4 Conductor Boxes -			#6	15.00	90
Painting -					
Walls and Ceilings - (2 coats Mill white)			2800 sq.y.	.35	980
Sash and doors - (2 coats)			1250 sq.y.	.45	563
Misc. iron					25
Engineering, plans, details etc.					750
Clean up job at completion & clean glass					125
Liability Insurance					750
Watchman 7 weeks @ $30.00					210
Superintendence, job overhead, office, stationery etc. 7 weeks @ $150					1050
Sundries					750
	Net Cost			$	37867
	Contractors profit, 12%			$	4544
	Total Estimate			$	42411

Items Not included
(1) Heating & Boilers
(2) Plumbing & Conductors, drains etc
(3) Electric Wiring
(4) Sprinklers
(5) Land

PART II—DETERMINING UNIT PRICES

I. General Considerations

The two principal elements which control unit prices in general are labor and material.

In order to arrive at a correct unit price for a certain building operation, it is essential to know very closely how much labor is involved in performing a unit of this work, and also how much material will be required. The items of labor and material must be estimated separately and then combined, the two together constituting the unit price to be used in the estimate. Every step involved should be carefully analyzed and correct values calculated for the labor and material in each one.

The unit prices used in the estimate sheets which have been illustrated in this text have been based on the labor rates and material costs prevailing in New England at the time of its preparation (August, 1919). Since, however, costs vary greatly in different localities and with changing markets for labor and material, the unit prices shown here should be viewed with caution for estimating purposes. They are given for showing method, not as offering a table of results. The volume of material and labor being priced has, too, an important bearing on the unit price. In short, it should always be borne in mind that a correct unit price for estimating purposes should be established after study of the circumstances and conditions peculiar to the particular job under consideration. It cannot be obtained in any other manner.

At the time when this paper goes to press, common laborers receive an average wage of 50 cts. per hour. Carpenters, masons, and other skilled building workers receive 90 cts. per hour. The unit costs shown on the accompanying estimate sheets are made up in accordance with the above labor rates. Adjustments should be made accordingly.

II. Concrete

Foundation Concrete. The unit price for the concrete in foundations is reached by first ascertaining the amount of material and labor necessary to make one cubic yard of concrete mixed, in this case, in the proportion of 1–3–6.

Experience has shown that to estimate the quantity of cement, sand, and crushed stone from the tables set forth in text books, which seldom allow for waste, is to encounter a shortage of materials. It will be noted that in working out the amounts of material in the following calculation, proper allowance has been made for inevitable waste.

Concrete — per cubic yard (1–3–6 mix)

Cement, $1\frac{1}{10}$ bbls.	@ $2.77 =	$3.05
Sand, $\frac{1}{2}$ cubic yard	@ 1.95 =	0.98
Cr. stone, $1\frac{3}{10}$ tons	@ 2.75 =	3.58
Plant		2.10
Labor, mixing and placing		1.75
Total cost per cubic yard		$11.46

(Use $11.50 for unit price.)

The price of cement above is that obtained from cement dealers ($2.84 per barrel f.o.b. cars, job). In this price is an allowance for 4 cement bags which, if returned to the dealer in good condition, will be credited at 10 cts. each or 40 cts. per barrel. A cash discount of 5 cts. per barrel is also allowed if payments are promptly made. If advantage of both these credits (45 cts.) is taken, the net cost of the cement becomes $2.39 per barrel.

Unloading and storing the cement in a cement shed costs usually 25 cts. per barrel. Tests must be made by the Cement Testing Bureau to ascertain the quality of the cement, for which an average charge of 3 cts. per barrel is made. The loss of credits due to injury to bags in transit and to the cost of freight on returned bags amounts to about 10 cts. per barrel of cement purchased. Allowance being made for the above charges, the price of cement becomes $2.77 per barrel and it is this figure which is used in working out the cost of concrete.

The following calculation shows in detail how this price is determined.

Cement — Dealer's quotation, f.o.b. cars job		$2.84
Credit for bags	$0.40	
Cash discount	0.05	0.45
		$2.39
Unloading and storing cement		0.25
Testing cement		0.03
Loss and freight on empty bags		0.10
Total cost per bbl.		$2.77

Sand — Dealer's quotation, f.o.b. cars job	$1.75
Unload and handle into bins	0.20
Total cost per cubic yard	$1.95

Crushed stone — f.o.b. cars job	$2.50
Unload and handle into bins	0.25
Total cost per ton	$2.75

Plant Cost. As a certain amount of machinery, chutes, runways, towers, etc., are required in the process of placing concrete, an allowance must be made in the unit price for the labor of erecting and dismantling this "plant work," as it is commonly called. Allowance must also be made for plant material purchased or rented for the duration of the job. This item varies with the size and type of the job. It may run as low as $1.00 per cubic yard, and, in especially difficult jobs, may run as high as $3.00 or more per cubic yard of concrete placed. A plant cost of $2.10 per cubic yard has been included in the unit price of the concrete estimated herein, and the sub-divisions of this cost are listed below.

Plant cost per cubic yard of concrete:

	Labor	Material or rental charge
Towers	$0.20	$0.20
Temporary buildings	0.12	0.15
Bins for aggregate	0.10	0.20
Mixer and motor	0.06	0.14
Canvas and chutes	0.05	0.35
Runway, staging and small tools	0.14	0.24
Fuel, power and water		0.15
Labor	$0.67	Material and Rentals $1.43

(Total per cu. yd. $2.10)

The average labor cost of mixing and placing concrete in a reinforced concrete building with common labor at 50 cts. per hour is about $1.75 per cubic yard when modern plant equipment is used on the job. A saving of 25 cts. on the labor cost and 25 cts. on the plant cost per cubic yard is usually made in placing paving concrete, making the unit for this class of work 50 cts. less than for other concrete work of a similar mix.

Column and Slab Concrete. The unit price of concrete mixed in the proportions of 1–2–4 and 1–1½–3 is made up in a similar way.

No change is made in the quantity of sand, crushed stone, labor and plant. The cement quantity alone is changed. The computation for 1–2–4 and 1–1½–3 concrete follows.

Concrete, per cubic yard (1–2–4 mix)

Cement, 1⅔ bbls.	@ \$2.77 =	\$4.62
Sand, ½ cubic yard	@ 1.95 =	0.98
Cr. stone, $1\frac{3}{10}$ tons	@ 2.75 =	3.58
Plant		2.10
Labor mixing and placing		1.75
Total cost per cubic yard		\$13.03

(Use \$13.00 for unit price.)

Concrete, per cubic yard (1–1½–3 mix)

Cement, 2 bbls.	@ \$2.77 =	\$5.54
Sand, ½ cubic yard	@ 1.95 =	0.98
Cr. stone, $1\frac{3}{10}$ tons	@ 2.75 =	3.58
Plant		2.10
Labor mixing and placing		1.75
Total cost per cubic yard		\$13.95

(Use \$14.00 for unit price.)

Window Sills. The unit price of concrete window sills of approximately standard size usually runs close to 72 cts. per linear foot, including concrete forms, reinforcement, and finish. The price of 72 cts. per linear foot is made up as follows:

Concrete	@ 50 cts. cu. ft. =	\$0.27½
Formwork	@ 25 cts. sq. ft. =	0.25
Reinforcement	@ 5 cts. lb. =	0.07½
Carborundum rubbing (outside)		0.12
Total cost per linear foot		\$0.72

Stairs and Landings. The cost of constructing reinforced concrete stairs, using rates of labor and materials as previously noted, is about \$1.50 per linear foot of nosing. Landings will cost about 75 cts. per square foot. These unit prices include all concrete, forms, reinforcement, and cement finish necessary to complete the stairway. No safety treads or hand rails are included.

Granolithic Finish. Granolithic finish 1 inch thick laid after the slab concrete has set will cost about 11 cts. per square foot for material and labor. The unit price is made up as follows:

1-inch Granolithic finish — laid after, — per 1000 square feet

Cement, 12½ bbls.	@ $2.77 =	$34.63
Peastone, 4 tons	@ 3.00 =	12.00
Labor to pick and clean floor preparatory to laying finish, mix and lay grano. finish including plant costs and protect while drying		65.00
Total cost per 1000 square feet		$111.63

(Use 11 cts. per square foot for unit price.)

Note. No sand is required in granolithic finish.

If the granolithic finish is laid before the concrete in the slab has become thoroughly dried out, the finish is called an integral finish. In estimating a finish of this kind, since the thickness of the granolithic finish is included in the slab concrete quantities, the unit price should contain only the labor cost of the cement finisher's time and the cost of the extra cement used in the top part of the slab which forms the finish, and the increased cost of using peastone instead of ordinary crushed stone. The unit price for integral granolithic finish is made up as follows:

1-inch Granolithic finish — laid integral — per 1000 sq. ft. per bbl.

Extra cement, 10 bbls.	@ $2.77 =	$27.70
Labor, finisher's time		30.00
Extra cost of peastone, 4 tons	@ 0.25 per ton =	1.00
Total cost per 1000 square feet		$58.70

(Use 6 cts. per sq. ft. for unit price.)

Cinder Concrete. The unit of cinder concrete crickets placed on the roof to form proper slope to downspouts has been worked out in detail as follows:

Cinder Concrete — per cubic yard

Cement, 1 bbl.	@ $2.77 =	$2.77
Cinders, 1 cubic yard		1.50
Plant costs		2.50
Labor, mix and place to slope		2.25
Total cost per cubic yard		$9.02

(Use $9.00 for unit price.)

Carborundum Finish. The cost of finishing concrete surfaces with carborundum stone and cement varies greatly with different contractors. A good finish may be obtained by going over the surface of the concrete twice at a total cost of about 7½ cts. per square foot of surface treated. The unit price is made up as follows:

Carborundum rubbing — 2 coats — per 1000 square feet

Labor, 1st rub		$40.00
Labor, 2nd rub		30.00
Cement used, ½ bbl	@ $2.77 =	1.38
Total cost per 1000 square feet		$71.38

(Use 7½ cts. per sq. ft. for unit price.)

III. Forms

General. In working out a unit price for formwork it is very important to know how many times the forms can be used without remaking. If it is possible to use the forms twice, one-half the cost of the lumber should be charged against the unit for each use. If the forms are used three times, a lumber charge of one-third the cost of the lumber is included in the unit price, and so on. The cost of erection and stripping the formwork remains uniform for each use, but some saving is made on making when the forms are used more than once. In forming one square foot of concrete surface, about 3 board feet of lumber are used in building the formwork. Hence, if the forms are used but once, the material charge in the unit price will be the cost of 3 board feet of lumber. If the formwork is used twice, it will be necessary to make a material charge of only 1½ board feet of lumber, and so on. Some salvage of the lumber is usually made at the completion of the job, except where the form work is very complicated and lumber is virtually ruined, in which case no salvage is realized. Ordinarily, however, a saving of about 15 per cent of the cost of the lumber is realized at the close of a job.

A certain amount of machinery is required with which the form work is constructed on the job. This consists principally of a saw mill and motor, small tools, nails, etc. This is the "plant cost," and seldom amounts to more than 1 ct. per square foot of concrete surface formed. The labor involved in making, erecting, and stripping the formwork varies with the complexity of the work, but seldom costs less than 7 cts., or more than 15 cts., per square foot of concrete surface formed. The cost of the labor of forming a concrete cornice or other similar work will be much more than this maximum.

Form Lumber. The unit costs for the formwork on the estimate sheets shown herewith have been worked out with lumber at $60 per M, f.o.b. cars at the job. Adding to this $2.50 per M to cover the cost of unloading and handling the lumber at the job, the price becomes $62.50 per M. The building will probably require a set of forms for one complete story, and, with a small amount of remaking, these forms may be used for forming the second or top story. This having been decided upon, it follows that the unit price should contain a material charge equal to the cost of 1½ board feet of lumber. This material charge is maintained throughout the unit prices for formwork so long as two uses are reckoned on. The determination of unit prices for the formwork used in the illustrative estimate are shown below.

The common labor is figured at 50 cts., and carpenters' work at 90 cts. per hour.

Footing Forms.

Lumber: 1½ board feet @ $62.50 per M =	$0.0938	
Deduct salvage	0.0150	
		$0.0788
Plant cost		0.0100
Labor, make, erect and strip		0.0800
Total cost per square foot		$0.1688

(Use 17 cts. for unit price.)

Foundation Wall Forms. The unit price for foundation wall forms may be figured similar to footing forms, with the exception that the labor will cost about 9 cts. instead of 8 cts. per square foot. This change adds 1 ct. per square foot to the unit price, making the unit price for foundation wall forms 18 cts. per square foot.

Exterior Column Forms.

Lumber: 1½ board feet @ $62.50 per M =	$0.0938	
Deduct salvage	0.0150	
		$0.0788
Plant costs		0.0100
Labor, make, erect and strip		0.1175
Total cost per square foot		$0.2063

(Use 20½ cts. for unit price.)

Bracket Forms.

Lumber: 1½ board feet........ @ $62.50 per M =	$0.0938
(no salvage allowed)	
Plant	$0.0100
Labor, make, erect and strip	0.2350
Total cost per square foot	$0.3388

(Use 33½ cts. for unit price.)

Interior Column Forms (Round Steel).

Rental of steel column forms, each	$15.00
Labor, erect, strip and handle	5.00
Total unit cost, each	$20.00

Flat Slab Floor and Roof Forms.

Lumber: 1½ board feet @ $62.50 per M =	$0.0938	
Deduct salvage	0.0150	
		$0.0788
Plant		0.0100
Labor, make, erect and strip		0.0775
Total cost per square foot		$0.1663

(Use 16½ cts. for unit price.)

Drop Panel Forms.

Lumber: 1½ board feet......... @ $62.50 per M =	$0.0938
(no salvage allowed)	
Plant	0.0100
Labor, make, erect and strip	0.1075
Total cost per square foot	$0.2113

(Use 21 cts. for unit price.)

Wall Beam Forms.

Lumber: 1½ board feet @ $62.50 per M =	$0.0938	
Deduct salvage	0.0150	
		$0.0788
Plant		0.0100
Labor, make, erect and strip		0.0975
Total cost per square foot		$0.1863

(Use 18½ cts. for unit price.)

Floor Beam Forms. The unit cost of floor beam forms works out quite closely to the cost of the wall beam forms, the only difference being an increase of about ½ ct. per square foot in the labor charge. This increase makes it necessary to use 19 cts. as a unit price for floor beam forms. Should the floor be what is known as a beam and slab type of floor the average labor cost of making, erecting, and stripping the forms, measuring beams and slab together will be about 8½ cts. per square foot. This will make the unit cost of beam and slab floor forms about 17½ cts. per square foot if the forms are used twice.

Partition Forms.

Lumber: 1½ board feet @ $62.50 per M =	$0.0938	
Deduct salvage	0.0150	
		$0.0788
Plant		0.0100
Labor, make, erect and strip		0.1375
Total cost per square foot		$0.2263

(Use 22½ cts. for unit price.)

IV. REINFORCEMENT

The labor of cutting, bending, and placing reinforcement will cost from $8.00 to $20.00 per ton, depending upon the size of the bar, the amount of bending required, and the position in which the bars must be finally placed. In the average concrete building it is safe to assume that a flat rate of $14.00 per ton will cut, bend, and place the reinforcement in the building. The unit price used in the accompanying estimate of 4¼ cts. per pound is made up as follows:

Steel Reinforcement.

Reinforcement f.o.b. cars, job, per ton	$68.00
Unload and pile on job	3.00
Cut, bend, and place, including wire, etc.	14.00
Total cost per ton	$85.00

(Use 4¼ cts. per lb. for unit price.)

CONCLUSION

It should be borne in mind that the preceding brief discussion of methods of determining unit prices makes no pretense of being other than an outline sketch of a subject whose exhaustive treatment might well occupy a good-sized volume. Its aim has been to indicate the proper direction of methods to be used, and to supply a sufficient number of illustrations to offer a clear exemplification throughout. The judgment and experience of the estimator, in any given instance, must be relied upon to evaluate the influence of modifying elements of time, place, and special circumstance.

APPENDIX G

DATA FOR ESTIMATING

From "Ransome Book" *

Brickwork. 8⅜ × 2⅜ × 4 inch brick with 5/16-inch joints require 12 cubic feet of mortar per 1000 brick. With a 1:3 cement and sand mix, 1 barrel of cement per 1000 brick. Allowing for waste 1.25 barrels of cement per 1000 brick. 1000 brick will lay 475 square feet of 12-inch wall.

Concrete Foundations — Walls, etc.

TABLE XLII

1 cu. ft. concrete-mix	Sacks of cement	1 cu. yd. concrete-mix	Bbls. of cement
1 : 1 : 1	0.5404	1 : 1 : 1	3.375
1 : 1½ : 3	0.2808	1 : 1½ : 3	1.895
1 : 2 : 4	0.2220	1 : 2 : 4	1.498
1 : 2½ : 5	0.1848	1 : 2½ : 5	1.247
1 : 3 : 6	0.1570	1 : 3 : 6	1.060

Floors, Walks, Roads, and Streets.

TABLE XLIII

Sacks of cement required for 1000 sq. ft. of surface								
Proportions	Thickness of course							
	1 ins.	2 ins.	4 ins.	5 ins.	6 ins.	7 ins.	8 ins.	9 ins.
1–2	3.9	7.88	....	....	....	....	....	....
1–1 –1	4.2	8.34	....	....	....	....	....	....
1–1 –1½	3.7	7.30	....	....	....	....	....	....
1–1½–2½	2.6	5.14	....	....	....	....	....	....
1–1½–3	....	....	9.36	11.70	14.04	16.38	18.72	21.06
1–2 –3	....	....	8.6	10.75	12.90	15.05	17.20	19.35
1–2 –4	....	....	7.40	9.25	11.10	12.95	14.80	16.65
1–2½–4	....	....	6.88	8.60	10.32	12.04	13.76	15.48
1–2½–5	....	....	6.16	7.70	9.24	10.78	12.32	13.86
1–3 –6	....	....	5.22	6.52	7.86	9.16	10.44	11.79

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* Courtesy Ransome Concrete Machinery Co.

Curbs and Gutters.

	1–2	Face.
	1–2½–5	Base.
	.28	Sacks per foot,
or	14.2	Feet per barrel of cement for Fig. 221,
and	.26	Sacks per foot,
or	15	Feet per barrel of cement for Fig. 222.

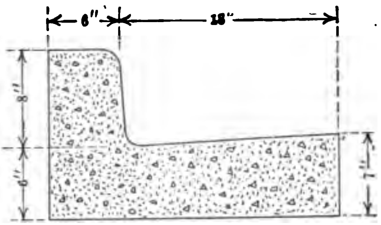

FIG. 221.

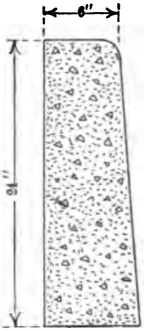

FIG. 222.

Grouting Brick Pavements. One barrel of cement for 30 square yards of brick pavement — 1–1 mix.

Amount of Cement Required for Street Improvements,* Base and Top.

TABLE XLIV

Mix	Bbls. of cement per sq. yd. paving or base				Bbls. of cement for 1 in. top	
	4 ins.	5 ins.	6 ins.	7 ins.		
1–1½–3	0.212	0.266	0.318	0.371	Mix	.....
1–2 –3	0.193	0.242	0.290	0.338	1–2	0.089
1–2 –4	0.168	0.210	0.252	0.294	1–2½	0.076
1–2½–5	0.138	0.172	0.207	0.241	1–3	0.066
1–3 –6	0.118	0.147	0.177	0.206		
+1–4	0.211	0.264	0.317	0.370		
+1–5	0.175	0.219	0.263	0.307		
+1–6	0.150	0.188	0.225	0.262		

* If gravel contains ¾-inch pebbles and smaller, reduce the quantity of cement about 10 per cent.

Garage Floors and Sidewalks.

TABLE XLV

MATERIALS REQUIRED FOR 1 CUBIC YARD OF CONCRETE

Mix	Cement, bbls.	Sand, cu. yd.	Stone, cu. yd.
1-1½-3	1.91	0.42	0.85
1-2 -3	1.74	0.52	0.77
1-2 -4	1.51	0.45	0.89
1-2½-5	1.24	0.46	0.92
1-3 -6	1.06	0.47	0.94

TABLE XLVI

Fig. 223 curb and gutter	Mix	Straight curb Fig. 224
Bbls. per lin. ft.		Bbls. per lin. ft.
0.084	1-2 -4	0.039
0.069	1-2½-5	0.034
0.059	1-3 -6	0.029
0.105	* 1-4	0.051
0.088	* 1-5	0.043
0.075	* 1-6	0.036

* If gravel contains ¾-inch pebbles and smaller reduce the quantity of cement 10 per cent.

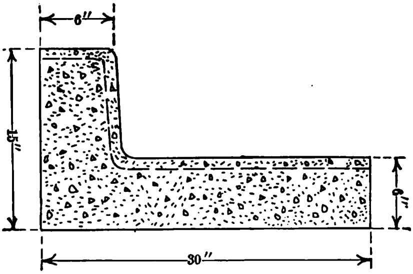

FIG. 223.

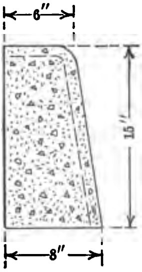

FIG. 224.

NOTE.—If mortar surface is specified add 0.01 bbl. per linear foot for Fig. 223, and 0.005 bbl. per linear foot for Fig. 224.

TABLE XLVII. — MATERIALS REQUIRED FOR 100 SQUARE FEET OF SIDEWALKS AND FLOORS FOR VARYING THICKNESS OF COURSE

CONCRETE BASE

Proportions	1 : 1½ : 3			1 : 2 : 3			1 : 2 : 4			1 : 2½ : 4			1 : 2½ : 5		
Thickness, inches	C.	Sd.	St.	C.	Sd.	St.	C.	Sd.	St.	C.	Sd.	St.	C.	Sd.	St.
2½	5.9	0.33	0.65	5.4	0.40	0.60	4.6	0.34	0.68	4.3	0.40	0.63	3.9	0.36	0.72
3	7.0	0.39	0.78	6.5	0.48	0.72	5.6	0.41	0.82	5.2	0.48	0.77	4.6	0.43	0.86
3½	8.2	0.46	0.91	7.5	0.56	0.84	6.5	0.48	0.96	6.0	0.56	0.89	5.4	0.50	1.00
4	9.4	0.52	1.04	8.6	0.64	0.95	7.4	0.55	1.10	6.9	0.64	1.02	6.2	0.57	1.14
4½	10.5	0.59	1.17	9.7	0.72	1.07	8.3	0.62	1.23	7.7	0.72	1.14	6.9	0.64	1.28
5	11.7	0.65	1.30	10.8	0.80	1.19	9.3	0.69	1.37	8.6	0.80	1.27	7.7	0.71	1.43
5½	12.9	0.72	1.43	11.8	0.88	1.31	10.2	0.76	1.50	9.5	0.87	1.40	8.5	0.78	1.57
6	14.0	0.78	1.56	12.9	0.96	1.43	11.1	0.82	1.64	10.3	0.95	1.53	9.2	0.86	1.72

WEARING COURSE

Thickness, inches	1 : 1		1 : 1½		1 : 2		1 : 1 : 1			1 : 1 : 1½		
	C.	Sd.	C.	Sd.	C.	Sd.	C.	Sd.	St.	C.	Sd.	St.
½	3.0	0.11	2.4	0.13	2.0	0.15	2.1	0.08	0.08	1.8	0.07	0.10
¾	4.5	0.16	3.6	0.19	2.9	0.22	3.1	0.11	0.11	2.7	0.10	0.15
1	6.0	0.22	4.8	0.26	3.9	0.29	4.2	0.15	0.15	3.7	0.14	0.20
1¼	7.5	0.27	6.0	0.33	4.9	0.36	5.2	0.19	0.19	4.6	0.17	0.25
1½	9.0	0.33	7.2	0.40	5.9	0.43	6.3	0.23	0.23	5.5	0.20	0.30
1¾	10.5	0.39	8.4	0.46	6.9	0.50	7.3	0.27	0.27	6.4	0.24	0.36
2	12.0	0.45	9.6	0.53	7.9	0.58	8.3	0.31	0.31	7.3	0.27	0.41

NOTE. Quantities expressed in the following units:

Cement........sacks Sand........cubic yards Pebbles or broken stone........cubic yards

TABLE XLVIII

MATERIALS REQUIRED FOR 100 SQUARE FEET OF SURFACE FOR VARYING THICKNESS OF PLASTER

Proportions	1 : 1		1 : 2½		1 : 2		1 : 2½		1 : 3	
Thickness, (in.)	C. (sacks)	Sd. (cu. yds.)	C. (sacks)	Sd. (cu. yds.)	C. (sacks)	Sd. (cu. yds.)	C. (sacks)	Sd. (cu. yds.)	C. (sacks)	Sd. (cu. yds.)
⅜	2.2	0.08	1.8	0.10	1.5	0.11	1.3	0.12	1.1	0.13
½	3.0	0.11	2.4	0.13	2.0	0.15	1.7	0.16	1.5	0.17
¾	4.5	0.16	3.6	0.19	2.9	0.22	2.5	0.23	2.2	0.25
1	6.0	0.22	4.8	0.26	3.9	0.29	3.3	0.31	3.0	0.33
1¼	7.5	0.27	6.0	0.33	4.9	0.36	4.2	0.39	3.7	0.41
1½	9.0	0.33	7.2	0.40	5.9	0.43	5.1	0.47	4.5	0.50
1¾	10.5	0.39	8.4	0.46	6.9	0.50	6.0	0.56	5.4	0.60
2	12.0	0.45	9.6	0.53	7.9	0.58	6.9	0.64	6.2	0.69

If hydrated lime is used it should be added in amounts of from 5 to 10 per cent by weight of the cement.
Hair is used in the scratch coat only in amounts of ⅛ bushel to 1 sack of cement.
These figures may vary 10 per cent in either direction due to the character of the sand.
No allowance is made for waste.

TABLE XLIX

QUANTITIES OF PORTLAND CEMENT, SAND, AND PEBBLES OR CRUSHED STONE

(For 100 Square Feet of Concrete 10 Inches Thick, Equal to 3.08 Cubic Yards)

Proportions			Quantities		
Sacks of cement	Cu. ft. of sand	Cu. ft. of pebbles or stone	Sacks of cement	Cu. yds. of sand	Cu. yds. of pebbles or stone
1	1	....	60.2	2.23	....
1	1½	....	47.7	2.65	....
1	2	....	39.4	2.92	....
1	2½	....	33.8	3.13	....
1	3	....	29.5	3.29	....
1	1	1	41.7	1.54	1.54
1	1½	3	23.4	1.30	2.60
1	2	3	21.5	1.59	2.38
1	2	4	18.5	1.37	2.74
1	2½	4	17.2	1.59	2.54
1	2½	5	15.4	1.43	2.86
1	3	5	14.2	1.58	2.64

The use of this table is illustrated by Example A and B

Example A. Required the quantity of materials for a 12-inch thick basement wall, 6 feet 5 inches high above footing, for a house 25 × 40 feet outside dimensions. The footing is 1 foot 6 inches wide and 6 inches thick. Concrete proportioned 1–3–5.

Wall.

Length of wall $25 + 25 + 39 + 39 = 128$ ft.
Height of wall 6 feet 5 inches $= 6\frac{5}{12} = 6.417$ feet
Area of wall $= 128 \times 6.417 = 821.4$ square feet
Thickness of wall = 12 ins.
Quantities of materials for wall concrete:
Factor for multiplying units in

$$\text{table} = \frac{821.4}{100} \times \frac{12}{10} = 8.214 \times 1.2 = 9.8568;$$

Take 9.86

Sacks of cement $= 14.2 \times 9.86 = 140$
Cubic yards of sand $= 1.58 \times 9.86 = 15.6$
Cubic yards of pebbles or crushed stone $= 2.64 \times 9.86 = 26.$

Footing.

Length of footing = 25.5 + 25.5 + 37.5 + 37.5 = 126 feet
Width of footing = 1 ft. 6 in. = $1\frac{6}{12}$ = 1.5 feet
Area of footing = 126 × 1.5 = 189 feet
Thickness of footing = 6 inches
Quantities of materials for footing:
Factor for multiplying units in the

$$\text{table} = \frac{189}{100} \times \frac{6}{10} = 1.89 \times 0.6 = 1.134 = 1.13$$

Sacks of cement = 14.2 × 1.13 = 16
Cubic yards of sand = 1.58 × 1.13 = 1.8
Cubic yards of pebbles or stone = 2.64 × 1.13 = 3

Total quantities of materials:
Sacks of cement = 140 + 16 = 156
Cubic yards of sand = 15.6 + 1.8 = 17.4 or 17.5
Cubic yards of pebbles = 26 + 3 = 29.

Example B. Required the quantities for a concrete floor for a basement. Interior dimensions of the basement 23 feet by 38 feet. Floor 5 inches thick over all, with 4-inch base of concrete proportioned 1:2½:5, and 1-inch wearing course composed of cement mortar proportioned 1:2.

Area of floor = 23 × 38 = 874 square feet
Factor for multiplying quantities in table for

$$\text{base} = \frac{874}{100} \times \frac{4}{10} = 8.74 \times 0.4 = 3.5$$

Quantities of materials for base concrete:
Sacks of cement = 15.4 × 3.5 = 54
Cubic yards of sand = 1.43 × 3.5 = 5
Cubic yards of pebbles or stone = 2.86 × 3.5 = 10
Factor for multiplying quantities in table for

$$\text{wearing surface} = \frac{874}{100} \times \frac{1}{10} = 8.74 \times 0.1 = 0.9$$

Quantities of materials for wearing surface mortar:
Sacks of cement = 39.4 × 0.9 = 35.5
Cubic yards of sand = 2.92 × 0.9 = 2.6 cubic yards.

Total quantities of materials for floor:
Sacks of cement = 54 + 35.4 = 89.5
Cubic yards of sand = 5 + 2.6 = 7.6 or 7.5
Cubic yards of pebbles or stone = 10.

TABLE L

SURFACE AREA (IN SQUARE FEET) OF CONCRETE SLABS OR WALLS OF VARIOUS THICKNESSES AND PROPORTIONS THAT CAN BE MADE WITH ONE SACK OF CEMENT

Thickness of slab or wall in inches	Concrete mixture				
	1 : 2 : 3	1 : 2 : 4	1 : 2½ : 4	1 : 2½ : 5	1 : 3 : 5
3	15.52	17.88	19.42	21.77	23.2
3½	13.31	15.33	16.65	18.67	19.9
4	11.64	13.41	14.56	16.33	17.4
4½	10.36	11.93	12.96	14.53	15.5
5	9.31	10.73	11.65	13.06	13.9
5½	8.46	9.74	10.58	11.86	12.6
6	7.76	8.94	9.71	10.88	11.6
6½	7.18	8.27	8.98	10.07	10.7
7	6.65	7.66	8.33	9.33	9.9
8	5.82	6.70	7.28	8.16	8.7
10	4.66	5.36	5.83	6.53	6.9
12	3.88	4.47	4.85	5.44	5.8
14	3.32	3.83	4.16	4.66	4.7
16	2.91	3.35	3.64	4.08	4.3

TABLE LI

WEIGHTS AND VOLUMES

Portland cement per barrel, net	376 lbs.
Portland cement per sack, net	94 lbs.
Natural cement per barrel, net	282 lbs.
Natural cement per sack, net	94 lbs.
Loose Portland cement averages per cubic foot	92 lbs.
Weight of paste made from Portland cement per cubic foot, averages	137 lbs.
Volume of paste made from 100 pounds of neat Portland cement averages	0.86 cu. ft.
Weight of Portland cement mortar in proportions of 1–2½ averages	135 lbs.
Weight of Portland cement concrete averages per cubic foot	130 lbs.
Cinder concrete averages	112 lbs.
Conglomerate concrete averages	150 lbs.
Gravel concrete averages	150 lbs.
Limestone concrete averages	148 lbs.
Sandstone concrete averages	143 lbs.
Trap concrete averages	155 lbs.

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